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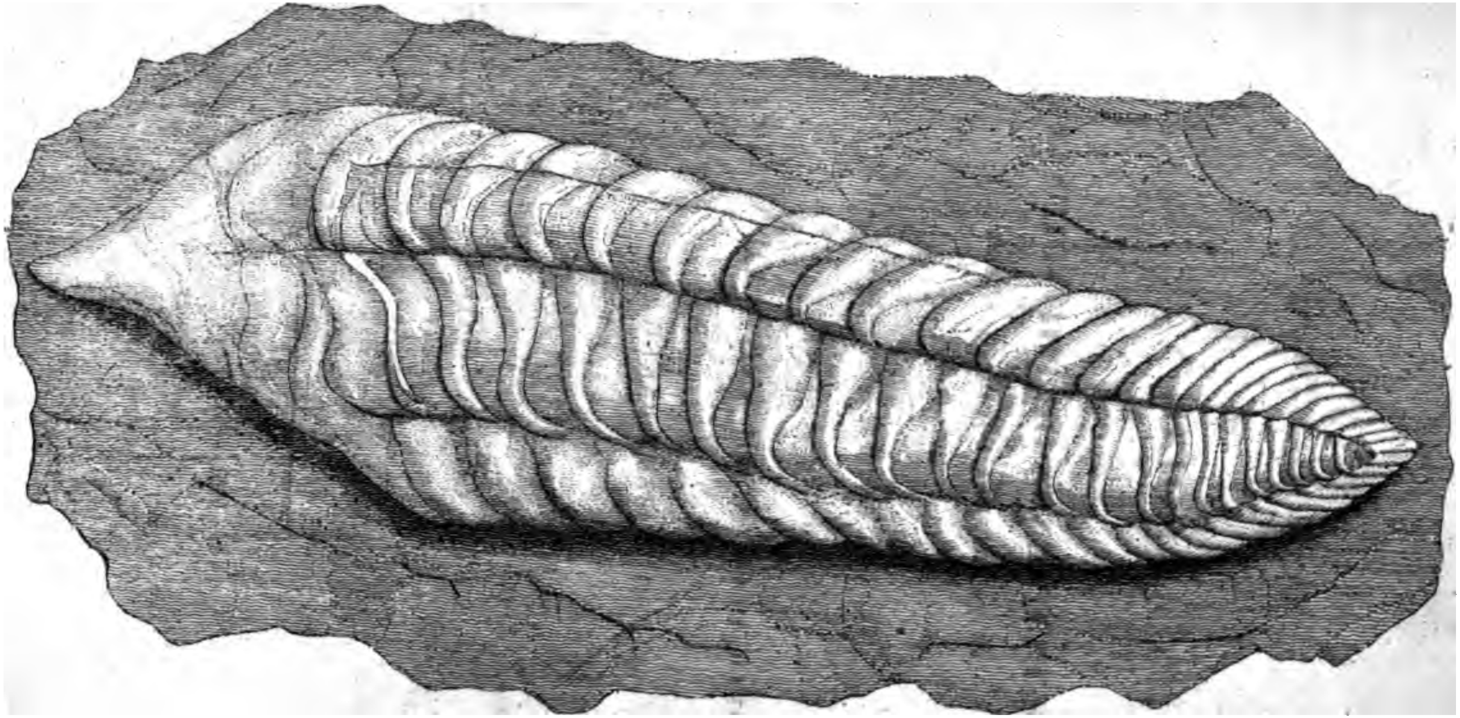

THE GIGANTIC TRILOBITE.
drawn the natural Size from a specimen in the Authors Collection.

AN

INTRODUCTION

TO

GEOLOGY:

COMPRISING

THE ELEMENTS OF THE SCIENCE

IN ITS PRESENT ADVANCED STATE,

AND

ALL THE RECENT DISCOVERIES;

WITH AN OUTLINE OF THE

GEOLOGY OF ENGLAND AND WALES.

BY ROBERT BAKEWELL.

LONDON:—THIRD EDITION,

ENTIRELY RECOMPOSED, AND GREATLY ENLARGED.—WITH NEW PLATES.

FIRST AMERICAN EDITION,

EDITED BY PROFESSOR SILLIMAN OF YALE COLLEGE, WITH AN
APPENDIX CONTAINING AN OUTLINE OF HIS COURSE
OF LECTURES ON GEOLOGY.

NEW HAVEN:
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1829.

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PREFACE

TO THE THIRD EDITION.

The First and Second Editions of the *Introduction to Geology* were favourably received, and sold off, soon after their publication. The work has since been translated and published in Germany, by Mr. Frederick Muller of Friburg; but it has been long out of print in this country. The causes which have retarded the publication of a Third Edition it is unnecessary to mention: the delay has, I trust, been favourable to its appearance in a very improved state; as I have been collecting materials for it, during several years, having visited almost every situation of much geological interest in our own island, from the Land's End in Cornwall, to the Grampian Mountains in Scotland; and passed part of three years in examining the geology of Savoy, Switzerland, and France. There is scarcely a rock formation described in the present volume, that I have not examined in its native situation, and compared with the descriptions of former geologists. I have also had opportunities of examining the collections, and of profiting by the communications, of some of the most eminent geologists on the Continent.

While engaged in these pursuits, I have not been inattentive to the labours of other observers. So numerous and interesting are the discoveries made in geology during the last ten years, that in order to present a concise view of the science in its present advanced state, the *Introduction to Geology* has been recomposed, and all the Chapters are greatly enlarged.

The following new Chapters have been added:—Chap. II. On Fossil Organic Remains. Chap. IV. On the Principles of Stratification. Chap. X. A Retrospective View of Geological Facts. Chap. XVIII. On the Destruction of Mountains; and on the Bones of Land Quadrupeds, found in Diluvial Depositions and in Caverns. Chap. XIX. On the Formation of Valleys; and on Deluges and Denudations.—The Plates are new, except Plate IV. and part of Plate VII. The Outline Map of the Geology of England and Wales, was I believe, when published in the First Edition of 1813, the only geological map of England that had then appeared. It presents in one view the grand geological divisions of the country, without delineating the different strata in each division. Mr. William Smith has since published a map of the Geology of England, which possesses extraordinary merit, when it is considered as the unaided attempt of one person, to trace the course of each rock formation through England and Wales. Mr. Greenough, and other members of the Geological Society of London, have subsequently published a geological map of England and Wales. This map, from the great variety of its useful details, and its general correctness, may be regarded as the most complete exhibition of the geology of an extensive country, that has yet appeared. It was thought, however, that the publication of my Map in its original form, (or nearly so,) would be acceptable to those who wished to gain a general knowledge of the geology of their own country, without entering into geological details; and that it would also serve as a useful introduction to the study of the above-mentioned maps.

In the course of the present work, I have frequently attempted to elucidate the geology of England, by comparisons with situations I have examined on the Continent, in order to connect the geology of our own island, with that of France, Switzerland, and Savoy.

By comprising the numerous facts and observations contained in the present volume, within the limits of an elementary work, from the desire to be concise, I may have run the risk of becoming obscure: this I have studiously endeavoured to avoid; my chief aim being to present the reader with a system of Geology, which shall explain geological phenomena in a clear and intelligible manner, and as free from technical obscurity as the nature of the subject would admit. In order that the price may not exceed that of the last Edition, this work is printed in a smaller type.

For any errors into which I may have inadvertently fallen, I would claim the candid indulgence of the reader, in the last words of that distinguished geologist Horace Benedict de Saussure, "*On peut être utile, sans atteindre à la perfection.*"

I shall conclude with some observations on the means of advancing geological knowledge. In a conversation I had with that experienced geologist Professor Brochant at Paris, on this subject,—he said: "We are already sufficiently rich in facts, what is now wanting, is an accurate review of these facts: many geological descriptions, on which much stress continues to be laid, were written in an early state of the science, and require such corrections, as a comprehensive view of recent discoveries could scarcely fail to suggest. I should recommend, Sir, that two active young men, competently instructed, should be sent out to examine all the most remarkable situations described by former geologists, and to note down their observations on the spot. They should travel together, not only for the sake of mutual comfort and assistance, in the solitary situations they might have to visit, but in the examination of dubious phenomena, that the observations of the one might correct or confirm those of the other."—These remarks of M. Brochant, which I have given as correctly as my memory and the difference of language would allow, well deserve the attention of all Geological Societies.*

What appears to me much wanted to clear up several dubious points in Geology, is a series of experiments, to ascertain the relative position and connection of certain rocks. This in some instances might be effected, by employing workmen to open out the edges of strata: other cases would require shafts to be sunk, and passages to be driven into the sides of mountains. Such experiments would be attended with expense; but they would reward us by the discovery of important facts, which must otherwise remain for ever unknown.

Hampstead, near London, March 10, 1828.

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* A Geological Map of France is at present in progress, under the direction of Professor Brochant.

PREFACES

TO THE FIRST AND SECOND EDITIONS ABRIDGED.

In tracing the progress of knowledge, we may frequently observe that the cultivation of particular branches of science at certain periods, was determined by causes which had little connection with their intrinsic utility. Fashion, caprice, and the authority of eminent names, govern mankind in philosophy, as well as on all other subjects. But, independently of accidental causes, there are leading objects in the universe, which, as nations advance in civilization, seem naturally to direct their attention to certain sciences in succession. The brilliancy of the sun, moon, and planets, their various motions, and connection with the changing seasons, would first arrest the attention of the rude philosopher; nor need we wonder, that he soon began to regard them as endowed with life and intelligence, and attributed to them a mysterious power over human affairs: thus the heavenly orbs became the objects of religious adoration; and curiosity, hope, and fear, lent their aid to the early cultivation of astronomy.

Mathematics and mechanical philosophy are so intimately connected with astronomy and the most useful arts, that they naturally claimed the second place among the early sciences.

The branches of philosophy which comprise a knowledge of the physical qualities of matter, or such as are perceptible by the senses, follow next; and at a later period, chemical philosophy or that science which endeavours to ascertain the elementary substances, of which all material objects are composed. In the order of succession, mineralogy and geology are the last of the natural sciences; for though an acquaintance with the earth is more important to man than a knowledge of the distant parts of the universe; yet, previously to the cultivation of the other sciences, and of chemistry in particular, our knowledge of the mineral kingdom could not extend much beyond that of the rudest periods. Thus we find that notwithstanding the precious metals, and many of the mineral treasures which the earth contains, have been the objects of insatiable cupidity in every age, yet, till the present day, almost all that was known of mineralogy, was confined to uneducated working miners.

In looking over the pages of history, we may observe that the most polished nations of antiquity had scarcely advanced beyond a limited acquaintance with astronomy, geometry, and mechanical philosophy. In modern Europe, all the natural sciences, geology and mineralogy excepted, have been successfully cultivated, and their progress has been astonishingly rapid; but till about the middle of the last century, the structure of the earth had scarcely engaged the attention of philosophers. Near that time, Lehman, the German, first observed that there are certain rocks which occupy the lowest relative situation in different countries, and that these rocks contain no organic remains: hence he gave them the name of primary, and established a division between them and the rocks by which they are covered, in which the remains of animals or vegetables frequently occur: the latter he called secondary. In our own country, the Rev. J. Michell, was the first person who appears to have had any clear views respecting the structure of the external parts of the earth: they were made public in a valuable paper on the cause of earthquakes, in the Philosophical Transactions, 1759. About twenty years afterwards, Mr. John Whitehurst published his "Inquiry into the original State and Formation of the Earth." His observations were principally confined to the rocks and strata of Derbyshire. Independently of its speculative opinions, this work was highly valuable, as an attempt to describe the geology of a district, from actual examination. The great variety of original information it contained, and its general accuracy, will remain a lasting monument of the writer's industry and ability. Mr. Whitehurst, however, fell into the same error with the celebrated Werner in Saxony, an error to which the first cultivators of geology were particularly exposed,—that of drawing general conclusions from local observations, and forming universal theories from a limited number of facts.

Though Mr. Whitehurst's book was favourably received, yet till the beginning of the present century, geological pursuits made little progress in England. On the continent, the researches of Saussure, Pallas, Werner, St. Fond, Dolomieu, and others, had before this time produced a powerful interest, and brought into the field many active and enlightened inquirers. The first general impulse given to the public taste, for geological investigations in this country, was produced by Professor Playfair's luminous and eloquent illustrations of the Huttonian theory. The leading feature of this theory, that all rocks or strata have been either formed or consolidated by central subterranean fire, was very warmly opposed; and much personal animosity and many adventitious circumstances were associated with the contest, not highly honourable to philosophy, but well calculated to keep alive the attention of the disputants, to those appearances in nature, which favored or opposed their different theories.

He who attempts to make a scientific subject familiar, runs the risk in this country of being deemed superficial: a plentiful share of dullness, combined with a certain degree of technical precision, are regarded as essential proofs of profundity. By prescriptive right, long established in these realms, dullness and pedantry guard the portals of the temple of Science, and command those who enter, to avert their eyes from whatever can elevate the imagination, or warm the heart, and to look at nature through a sheet of ice. In compliance with their authority, writers of introductory treatises, have generally thought it necessary to avoid that felicity in the familiar illustration of scientific subjects, so conspicuous in some of the elementary works of our neighbours. Without venturing to depart too far from established usage, I have endeavoured to render geology more intelligible, by avoiding as much as possible theoretical, and technical language, and by introducing a simple arrangement, suited to the present state of our knowledge. The local illustrations from various parts of our island, with the drawings, sections, and map in the present volume, will I trust facilitate the study of geology, and prove particularly acceptable to those who are entering on these inquiries: at the same time, I flatter myself with the hope, that the original information this work contains, respecting the geology and natural history of England, will secure it a candid reception.—*Edition of* 1813.

Several have been deterred from the study of geology by the supposed difficulty of learning its attendant science, mineralogy; but an acquaintance with the nice distinctions made by many modern mineralogists, is not necessary to gain a knowledge of the structure and arrangement of the great masses of matter that environ the globe, nor of the substances of which they are composed. He who would gain a useful knowledge of geology, would do well to provide himself with specimens of common rocks, and the simple minerals of which they are composed, and examine their external characters and physical properties, comparing them with the description given by the best mineralogical writers. Fortunately these substances are not very numerous, and he may (without present inconvenience) omit the more rare crystallizations and varieties, so much valued by cabinet philosophers; for here, as in many other instances, the received value, is in an inverse ratio of the utility. The pedantic nomenclature, and frivolous distinctions recently introduced into mineralogy, may gratify vanity with a parade of knowledge; but they are unconnected with objects of real utility, or with any enlarged views of nature.

On hearing the various names which mineralogists give to the same substance, and observing the avidity with which each new name is seized, as if it conveyed a hidden charm, the uninitiated might suppose, that he was "journeying in the land of Shinar," and had fallen in company with a set of masons fresh from the tower of Babel, each one calling the same stone by a different name, and glorying in his absurdity. Such frivolities disgust men of sense with the study of an important and interesting science; a science that has for its immediate object, the structure of the planet which the Author of nature has destined for our abode, and an acquaintance with the situation of its various mineral productions, subservient to the wants or enjoyments of man in civilized society.

The advice of Cicero to the cultivators of moral science applies with peculiar force to the geologists and mineralogists of the present day. "In these natural and laudable pursuits, two errors are particularly to be avoided: the first, not to confound those things of which we are ignorant with those we know, or rashly to yield our assent without due investigation; the second, not to bestow too much labour and study on obscure, intricate, and unprofitable subjects." "In hoc genere et naturali et honesto, duo vitia vitanda sunt: unum, ne incognita pro cognitis habeamus, hisque temere assentiamur (quod vitium, effugere qui volet adhibebit ad considerandas res et tempus et diligentiam.) Alterum est vitium, quod quidam nimis magnum studium multamque operam in res obscuras atque difficiles conferunt, easdemque non necessarias."—*Cic. Offic.* i. 6.

PREFACE

TO THE AMERICAN EDITION.

Geology has become an interesting and important branch of human knowledge.

It is founded, exclusively, on observation, and availing itself of all accessible sources of information, it has already accumulated an astonishing amount of valuable and instructive facts.

It is subservient to very important purposes in human society, and furnishes a ceaseless fund of entertainment and instruction to the observer whose curiosity is directed by sufficient information. The facts of the science are entirely independent of the theoretical speculations, which are often built upon them; and will remain unimpaired in value, when some of those speculations have passed into oblivion.

The editor, believes that he is performing a service to his country, by encouraging the republication of a work, conspicuous for attractiveness—for perspicuity—for a style generally vigorous and correct—often eloquent and beautiful; and for an independence of spirit, which carries the author straight forward to his object, certainly without any servile regard to previous systems. While bestowing this merited commendation, we do not mean to say, that we fully adopt all the author's theoretical views, although most of them appear to be philosophical and just, and some of them are peculiarly happy. We know not of any work on geology, which, as *an introduction*, can be perused with more advantage than this.

We trust that the author, still vigilantly watching the progress of the science, (no where supported by such liberal and active patronage and by so many gifted cultivators as in his own country,) will, at no distant day, furnish a still more extended edition, enriched with new facts and views.

Perhaps it may have been expected, that in the present edition, more facts relating to American Geology would have been introduced. This would have been done, to a much greater extent, had not the annunciation of Professor Eaton's American Geology,* authorized us to expect the fuller performance of this duty by him, and with a direct reference to a comparison with the Geology of the Eastern Continent.

Speaking in the character of a public instructor of youth, I beg leave to add, that my immediate motive for recommending this republication, was, that I might place in the hands of my own classes, a comprehensive treatise on geology, which they would be *willing* to read, and *able* to understand: I have been induced also, with the view of rendering my own course of instruction in this science more intelligible and useful to them, to add, in an appendix, (although with some repetition of ideas contained in the author's text,) an outline of some of the principal topics, which I am accustomed to discuss, in my public lectures on geology; not wishing however to attach more importance to my own deductions, than may be fairly justified by *facts*, which, when they are accurately ascertained, and faithfully reported, constitute the true riches of geology, although theory has also, as in other cases, an appropriate and important value.

B. SILLIMAN.

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* American Journal of Science and Arts, Vol. XIV, p. 400.

Yale College, Jan. 1, 1829.

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CHAPTER XIX.

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CHAPTER XX.

AN OUTLINE OF THE GEOLOGY OF ENGLAND AND WALES.

Geology of England and Wales.—The principal mountain range on the western side of the island denominated the Great Alpine Chain.—Divided into three groups or ranges.—Mineral treasures of the Devonian range.—Mountains of the Cambrian range and principal mineral treasures.—Extent of the Northern range.—Structure of the calcareous mountains explained by a section of England.—Mountains surrounding the Lakes.—Branch from the Northern range extending into Derbyshire.—These three ranges comprise the Alpine districts.—The middle district, coal fields in it enumerated.—This district in some parts covered by red marle and sandstone containing rock-salt and brine springs.—Primary rocks and ancient trap rocks appear in the middle district, at Charnwood Forest, in Warwickshire, Gloucestershire and Somersetshire.—The upper calcareous district contains no beds of good coal nor any metallic veins.—Extent of the Magnesian limestone bordering the coal strata.—Extent and duration of Lias limestone through England.—Range of Oolite limestone through England and its abrupt termination.—Strata between the oolite and chalk.—Extent of chalk in England.—Tertiary formations covering chalk.—Alluvial and diluvial depositions.—Subterranean and submarine forests.—Thermal waters of England.—Observations on the total thickness of the different rock formations of England.—On coal districts concealed by upper calcareous strata.—On the cause which prevented the further extension of the oolite and lias to the north-west. 356

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DESCRIPTION OF THE PLATES.

PLATE V.

THE GIGANTIC TRILOBITE of the natural size *(to face the title.)*

From a specimen in the Author's collection.—This specimen was taken from the slate quarries at Angers in France. The animal has received the name of Ogyges; it is supposed to be one of the oldest inhabitants of the globe. The living animal which resembles it the most, is the Monoculus Apus.

PLATE I.

Fig. 1. 2. 3. 4. 5. 6. Illustrations of plane and curved stratification. (See Chap. IV.)

PLATE II.

Fig. 1. Overlapping strata with straight edges.

Fig. 5. Overlapping strata with curved edges.

Fig. 2. Structure of a part of the Alps, representing the beds, nearly vertical, that approach the central range, and the bended stratification of the outer ranges. The dotted lines represent the supposed extension of the beds at the period of their elevation. *d d.* granite and mica-slate. *c c.* beds of soft slate. *a a a. b b.* beds of limestone, sandstone, and conglomerate.

Fig. 4. A section representing the arrangement of the rocks and strata at Charnwood Forest in Leicestershire, from the manor of Whitwick, to near Barrow-on-Soar. In this section the proportions of distance are disregarded, in order to bring the different rock formations within the space of the plate. *a a a.* stratified sandstone. *b b.* rocks of granite, sienite, and porphyry. *c c.* slate-rocks of Swithland quarry; the beds much elevated. *d d.* coal strata, rising towards the granitic and slate-rocks. *e.* lias, covering the red marle. It is obvious from this arrangement, that the strata of sandstone *a a a.* were deposited upon the slate-rocks and granite, after the beds had been raised into their present position; whereas in Fig. 2. the beds *a a.* have evidently been deposited before the beds of granite in the Alps were elevated; and as these beds *a a.* are of more recent formation than the sandstone *a a.* in Fig. 4. their position proves decidedly, that the beds of granite in the Alps, were elevated after the beds of granite and slate in Leicestershire. (See Chap, X.)

Fig. 3. A granite vein in slate.

Fig. 6. The remaining portion of a thick bed of limestone forming an isolated mass *b.* on a mountain in Savoy. *a a.* the former extent of a bed. *c c.* a bed of soft sandstone.

PLATE III.

Fig. 1. The conformable position of rocks. *a.* granite. *b.* gneiss. *c.* mica-slate. *d d.* slate. *x x.* a subordinate bed of limestone on slate. 2. a bed of conglomerate. *e e.* transition limestone and greywacke. *e.* upper conglomerate. F F. coal strata.

Fig. 2. A. Unconformable massive rocks. A thick bed of porphyry or basalt, C. C. covering the transition rocks 1. 2. 3. and dykes of porphry or basalt intersecting transition rocks.—N.B. The porphyry at Christiania in Norway occurs in this position; the lower part of it is amygdaloidal basalt; the middle part porphyritic, which passes in the upper to beautiful sienite and common granite. (See page 142.) The rocks B. on the right, represent the three modes of basalt;—a columnar bed, *d.* with a vertical dyke of basalt, and beds of interposed basalt. *b.* is an isolated cap of columnar basalt.

Fig. 3. Unconformable strata of sandstone, covering coal strata on the side of the dip B. and on the side of the rise D. (See page 130.)

Fig. 4. A section representing the general arrangement of the strata near Dudley. A. Wren's Nest Hill. *a, b.* two elevated beds of limestone, the lower of which is worked by horizontal passages over each other. The beds of limestone are folded round the hill, as represented in the small compartment, E. which is an horizontal section of the two beds of limestone *a, b.* The thirty feet bed of Staffordshire coal, C. is seen cropping out near the foot of Wren's Nest Hill. B. the arrangment of the limestone strata at Dudley Castle Hill. D. a hill, capped with basalt. In this section the proportion of distance has been disregarded, for the same reason as in Plate 2. fig. 4.

PLATE IV.

Fig. 1. Arrangement of the strata from Sheffield in Yorkshire to Castleton in Derbyshire. (See page 57.)

Fig. 2. Coal strata, arranged in basin-shaped concavities, and intersected by a fault. (See page 113.)

Fig. 3. Coal strata thrown up by a broad dyke. (See pages 114 and 115.)

Fig. 4. Metallic veins. *a a.* a vein divided by the vein *b b.* *c c.* a pipe vein.

Fig. 5. Metallic veins in limestone, cut through by toadstone.

PLATE VI.

Outline Map of the Geology of England and Wales, and a section of the Vale of Thames.

PLATE VII.

Fig. 1. A section of England through Durham and Cumberland. The remaining figures in this plate are sections and ground plans of metallic veins, (See Chapter XVII.) and a group of columnar trap-rocks.

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DIRECTIONS TO THE BINDER.

The Gigantic trilobite, *to face* the title.
Plate I. II. III. IV. VI. VII. *to face* Chapter I.

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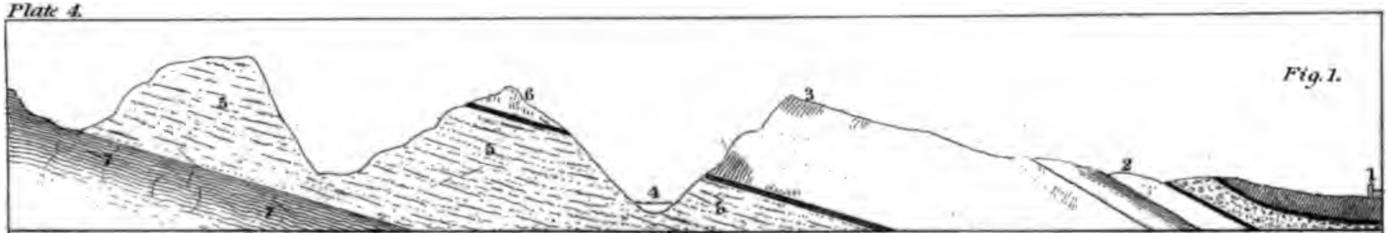
Plate 4.



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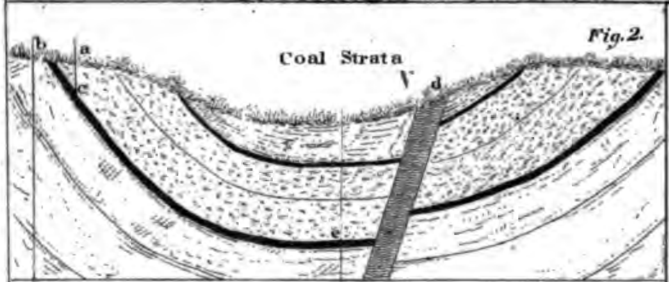

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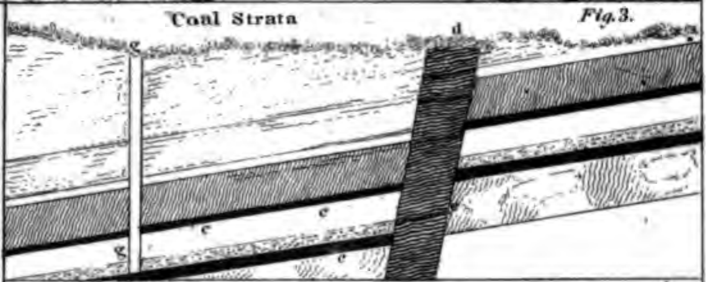

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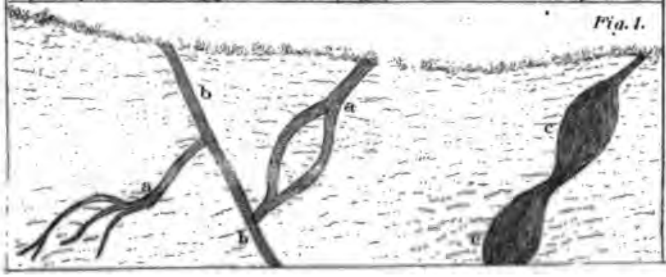

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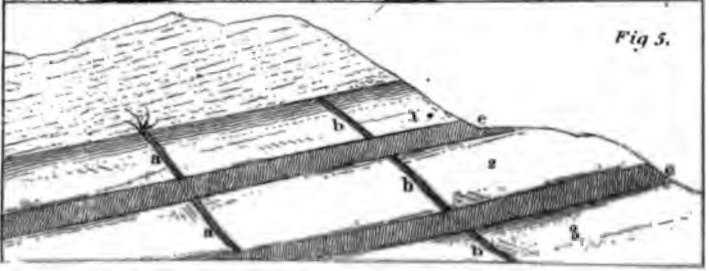

Fig 5.

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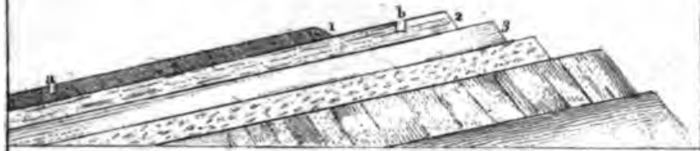
Plate 1.

Fig. 1.



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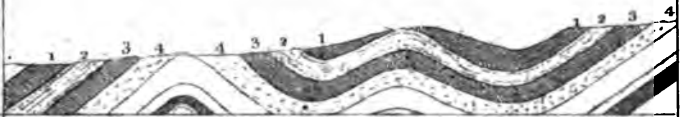

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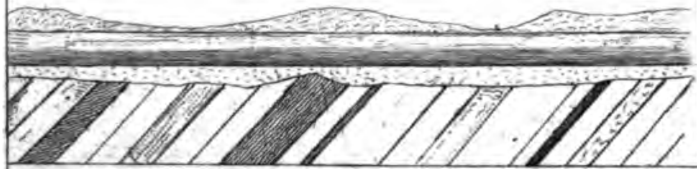

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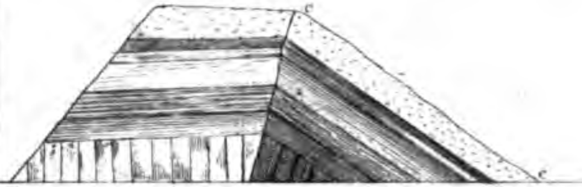

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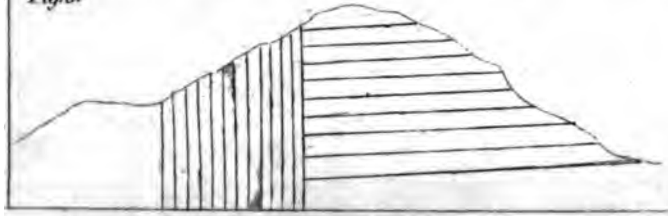

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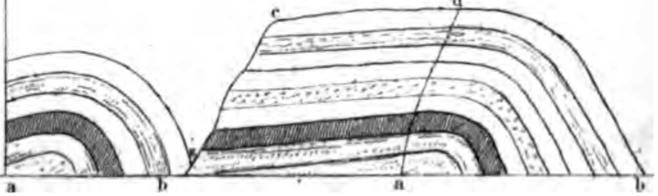

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of the ~~earthy~~ crust of the earth,

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INTRODUCTION TO GEOLOGY.

CHAPTER I.

Objects of the Science denominated Geology.—The Shape and Density of the Earth.—Opinions respecting the internal Parts of the Globe.—Sea and dry Land.—Proportion of the Earth's Surface habitable by Man.—On the Appearances which led to the first Division of Rocks into Primary and Secondary.—Classification of Rocks.—Districts in which the different Classes appear in England.—The present Islands and Continents formerly covered by the Ocean.—Existing Proofs of this in Great Britain and various Parts of the World.—Fossil Remains of marine Animals, Vegetables, and land Quadrupeds; the Strata in which they are imbedded formed in Succession at different Epochs.—On human Bones occasionally imbedded in Rock.—Inferences respecting the former Condition of the Globe.—Remarkable Passage in the Institutes of Menu.

There are perhaps few persons possessed of much curiosity in early life, to whom the following question has not frequently presented itself—*What is the world made of?* Now this question, with certain conditions, comprises the most important objects of geological research; namely, *What are the substances of which the Earth is composed? What is the order in which they are arranged? What are the changes they appear to have undergone?*—But how are satisfactory answers to these inquiries to be obtained?

When we examine the terrestrial globe, where the solid parts are uncovered and exposed to our view, we observe vast masses of rock or stone lying in apparent confusion on each other; or, should we perceive some regularity in their position and arrangement, we soon lose sight of it again by the intervention of other rocks. In this department of nature all seems vast, unshapen, and chaotic; but let us not be discouraged, for we may recollect that the grandest objects in the material universe, seldom present to the hasty view of the superficial observer, immediate proofs of order or design.

The shepherd who first discovered that the planets were not fixed in the heavens, and noticed their apparently intricate wanderings among the stars, could not possibly anticipate the regularity and harmonious simplicity of their movements, which subsequent observations have demonstrated.

Let us then endeavour to ascertain by what means we may become acquainted with the structure of the solid covering of our globe. Were these means bounded by the power of man to penetrate below the surface, our knowledge must ever remain very limited and imperfect; but natural operations have greatly facilitated our inquiries, and have broken the rocky pavement of the globe, and raised up or laid bare the mineral substances of which it is composed. By an attentive examination of the situations where the rocks and strata are thus exposed to our research, we lay the foundations of the science denominated Geology.

Geology is derived from two Greek words, γη "the earth" and λογος "reason" and signifies the Science of the Earth. Werner and his disciples, and also some of the French geologists, have changed the term into *Geognosy;* but for this change no sufficient reason can be assigned, and it is contrary to established analogies of language.* Philosophers in former ages, neglected the examination of the earth, and contented themselves with vain speculations respecting its formation; whereas the only proper answer to the question, *How was the world made?* is briefly this—"By the almighty power of its Creator." We may however be permitted, and indeed we are almost irresistibly impelled to inquire into the nature of the secondary causes, that have been operative in reducing the surface of our globe to its present state. This inquiry comprises what may properly be denominated Speculative Geology. Nor is this, as some assert, entirely useless: the advocates of particular systems have engaged in an active examination of nature to support their opinions, and have "compassed sea and land to gain proselytes:" thus numerous facts have been discovered, with which we should not have been acquainted had they remained idle in their studies.

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* Nothing can be more unmeaning than the apologies that have been offered for substituting γνωσις (*gnosis*) "knowledge," for λογος (*logos*) "reason." By the same rule we ought to change meteorology, physiology, &c. into meteorognosy, physiognosy, &c.

The earth is now well known to be one of those globular bodies called planets, that revolve round the sun in orbits nearly circular, and in stated periods of time which bear a certain ratio to their respective distances from it. They turn round their axes with different degrees of velocity; and this motion appears to have had considerable influence on their external shape, by enenlarging their equatorial diameters; they are not perfect spheres, but are more or less flattened at their poles.

In the planet Jupiter, the velocity of the equatorial parts is more than four hundred miles per minute, whilst in the same time the equatorial parts of the Earth have moved only seventeen miles. A difference between the polar and equatorial diameter of Jupiter is perceptible with a telescope that has a distinct magnifying power of a hundred times, and it is ascertained to be as twelve to thirteen. The equatorial diameter of the earth exceeds its polar about twenty-seven miles; the length of the equatorial diameter being seven thousand nine hundred and twenty seven, that of the polar seven thousand nine hundred miles.

The relative density of the sun, the earth, and of the other planets, is estimated by the attractive force which they exert on each other, as they move round their common centre of gravity. The absolute density or the quantity of matter contained in the earth, compared with an equal bulk of any known substance, may be nearly determined by the attractive force which any given mass of matter exerts upon a plummet (when suspended in its vicinity) to draw it from a vertical line. This will be proportional to the absolute quantity of matter in that mass compared with that of the earth. By this method, it has been found that the mean density of the earth is about five times greater than that of water, or nearly twice the average density of the rocks and stones on the surface.

whole surface of the earth is a crust of oxides

Hence it may be inferred that the interior part of the earth is solid; or, if it be cavernous, the solid matter must possess great density. It is not improbable that iron, nearly in a metallic state, may be one of the constituent parts of the central mass, and to this it may owe its magnetic polarity.

Dr. Halley has written a very ingenious paper in the Philosophical Transactions, to prove that the earth is a hollow sphere, in which there is inclosed a central magnetic globe, and by the motions of this globe the variations of the magnetic needle are produced. The celebrated French astronomer Laplace asserts that the nutation of the earth's axis, and experiments on the vibration of the pendulum, indicate that the mineral beds of which our planet is composed, increase in density as they approach nearer to its centre, at least to a certain depth from its surface. There are, however, terrestrial phenomena, such as the rapid transition of motion to very distant parts of the earth's surface during violent earthquakes, which would render probable the existence of interior cavities filled with fluid or gaseous matter, extending from one quarter of the globe to the other, and from the lower parts, to near the surface. It is evident that we have no means of verifying or invalidating hypotheses respecting the nature and structure of the central parts of the globe. The matter thrown up from vast and unknown depths by subterranean fires is similar to that of many rocks on the surface; but we know not what changes it has undergone, or what substances were separated from it by fusion.

It is however, the study of the crust of the globe that is the proper occupation of the Geologist; and the greatest depth to which he can extend his observations from the uppermost strata, to the very lowest beds that have been raised up or laid bare by these natural operations which have formed mountains or valleys, is less than eight miles; a thickness which compared with the bulk of the earth itself, does not exceed that of a coat of varnish upon an artificial terrestrial globe. Were we to bear this sufficiently in mind, the mighty catastrophes which have changed the surface of the globe in former periods, and have left traces of their action, appalling to the imagination, would cease to exceed the sober measure of belief.

The superficies of our planet is calculated to contain about one hundred and ninety millions of square miles; but could we be raised to a sufficient height above the earth, so as to have its whole enlightened hemisphere for our horizon, we might perceive as it revolved under our feet, how small a portion is fitted for the habitation of man. More than three fifths of the earth's surface are covered by the ocean; and if from the remaining part we deduct the space occupied by polar ice and eternal snow, by sandy deserts, steril mountains, marshes, rivers and lakes, the habitable portion will scarcely exceed one fifth of the whole of the globe. Nor have we reason to believe that at any former period, the dominion of man over the earth was more extensive than at present. The remaining four fifths of our globe, though untenanted by mankind, are for the most part abundantly stocked with animated beings, that exult in the pleasure of existence, independent of human control, and no way subservient to our necessities or caprice. Such is and has been for several thousand years the actual condition of our planet; nor is the consideration foreign to our subject, for hence we may feel less reluctance in admitting the prolonged ages or days of creation, when numerous tribes of the lower orders of aquatic animals lived and flourished, and left their remains imbedded in the strata that compose the outer crust of our planet.

The ocean has been an important agent in effecting vast changes on the surface of our globe, which will be afterwards considered. The average depth of the sea has been differently estimated; according to Laplace this depth cannot be less than ten miles, to account for the height of the tides by the laws of gravitation. No admeasurement by soundings has exceeded the depth of one mile and a quarter.

The ocean has not always been confined in its present bed, for rocks almost entirely composed of the shells or remains of marine animals, are found in almost every country that has yet been explored, and these remains occur near the summits of the highest mountains, in the old and new continents, some of which rise more than two miles above the present level of the sea.

It is well known that the water of the sea contains a considerable portion of common salt, and a small portion of other saline ingredients.* The average amount of salt in the ocean may be estimated at 2½ per cent. of common salt and ½ per cent. of other saline compounds.

The atmosphere which surrounds the earth does not come under the attention of the geologist, except as an agent in wearing down the surface by moisture and change of temperature.

The inequalities of the earth's surface formed by mountains and valleys, afford frequent opportunities for observing that the mineral substances of which it is composed, are of different kinds: in some situations we observe strata of chalk; in others, of sandstone or limestone, or beds of slate, granite, &c. It was long known to working miners that the different beds of mineral matter lay over each other in a regular order in certain districts, and that certain beds were always found under and never above other particular beds.

The first geological observation which may be said to have laid the foundation of the science, was made by the German Lehman. He found that the lower rocks in some of the mining districts were distinguished from the upper rocks by their great hardness and by their structure, which was for the most part either crystalline or slaty; they were also distinguished by the absence of shells and other organic remains, and by the absence of fragments of other rocks which occur so frequently in the upper rocks or strata. He further observed that many of the upper strata, besides containing organic remains, appeared to have been formed of fragments of the lower rocks, broken down and agglutinated together; and hence he inferred, that the lower rocks were formed prior to the creation of animals, and he gave them the name of *Primitive or Primary*, and distinguished the upper by the name of *Secondary*. This grand division, though too hastily formed, was of use in the infancy of the science, and induced geologists to examine more attentively the nature and position of the rocks in different countries: and as their observations became more extended and accurate, a more extended arrangement and classification was found necessary. Many of the earlier geologists maintained, that each bed or stratum of rock is extended universally over the globe, and that a series of beds in regular succession environs our planet like the coats of an onion. This position is, however, much too general, as many beds of rock which are common in one country, are entirely wanting in another; but taken as an illustration of the structure of the crust of our globe over a limited extent, the successive coats of an onion, if they were of different colours, might not unaptly represent the different strata that cover certain districts.

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* The inquiry has often been made—Whence did the sea derive its saline contents? It has been supposed by some writers that the salt in the sea has been gradually augmented by saline particles brought into it by rivers; but this cause is totally inadequate to explain the immense quantity of salt existing in the whole mass of the ocean. If the average depth of the sea be ten miles, and it contains two and a half per cent. of salt,—were the water entirely evaporated, the thickness of the saline residue would exceed one thousand feet; and were this removed and spread over all our present continents, it would form a stratum of solid rock-salt more than half a mile in thickness.

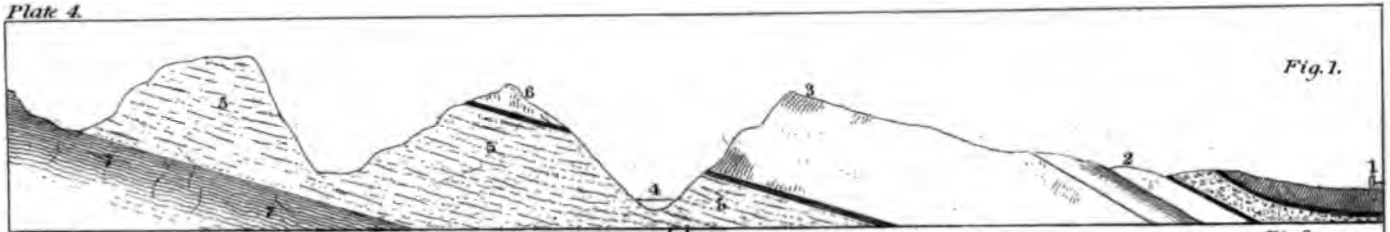
It may here also be proper to observe, that the different strata which occur under each other are not arranged in the order of their density or specific gravity. Coal strata, for instance, are often covered with strata of iron-stone, the specific gravity of which is more than twice that of coal.

I shall now proceed to enumerate the different classes of rocks generally admitted by geologists, and briefly describe the principal characters of each class; and in order to direct the attention of the reader more forcibly to the subject, I shall trace on an outline map the principal situations in our own island, where rocks of each class occur, except the recent volcanic.

All the different rocks and strata that cover the earth's surface may be arranged under the following classes:—

1. Primary.
2. Intermediate or Transition. calld medial
3. Secondary; comprising
   The Lower Secondary Series, and
   The Upper Secondary Series. super medial

Plate 4.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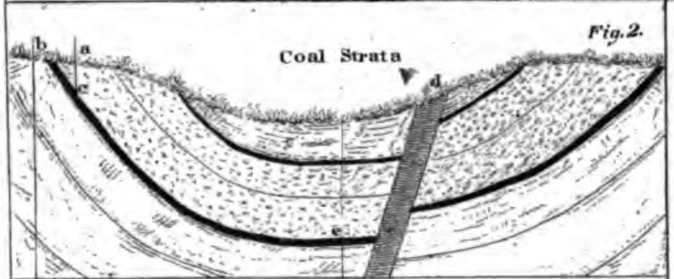
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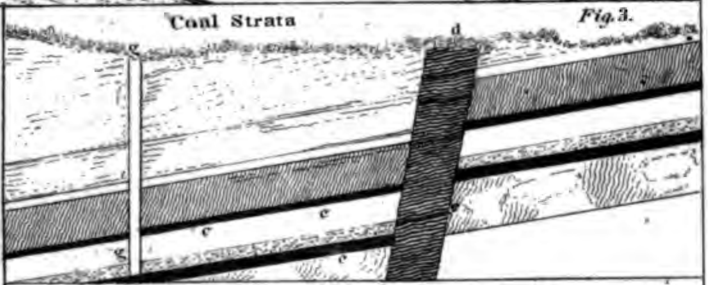
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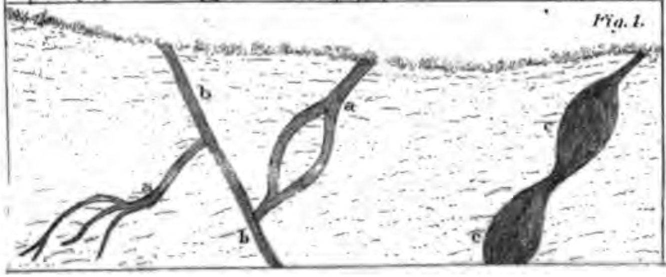
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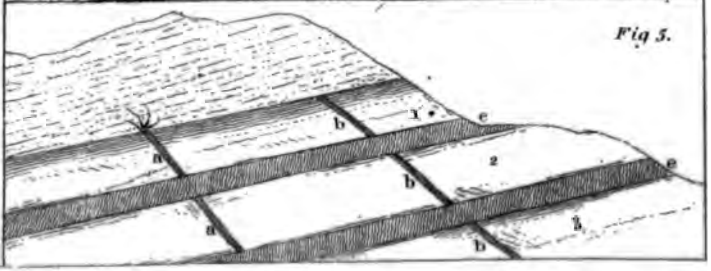
Fig 5.

Ashby-de-la-Zouch, in Leicestershire: it will evince how cautious we ought to be in drawing general conclusions in geology, from single facts. A thick bed of coal belonging to his lordship, at a place called Ashby Wolds, is worked at the depth of two hundred and twenty-five yards; it is covered with various strata of ironstone, coal, and solid sandstone. On an estate adjoining to his lordship's manor, in the same bed of coal, (which is ninety-seven yards below the surface,) the entire skeleton of a man was found imbedded. No appearance existed of any former sinking for coal; but the proprietor ordered passages to be cut in different directions, until the indication of a former pit was discovered, though the coal had not been worked. Into this pit the body must have fallen, and been pressed and consolidated in the loose coal by an incumbent column of water, previously to the falling in of the sides of the pit.

The imperfect skeleton of a woman, imbedded in a kind of calcareous sandstone, brought from Gaudaloupe, and exhibited in the British Museum, may appear to invalidate what was asserted in the first edition of this work, that no instances have been known of human bones being found in regular stratified rocks, nor even in undisturbed alluvial ground, where the remains of extinct species of quadrupeds are not unfrequently met with*. Due attention to all the circumstances, will reconcile that assertion with the present fact. The skeleton from Gaudaloupe is described as having been found on the shore below the high-wa-

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* Since the publication of the first and second editions of this work, I have seen in the possession of a gentleman at Plymouth, one of two human skulls that were found in digging a stream work forty or fifty feet below the level of the river at Carnon in Cornwall. Nuts, and the horns of some animal allied to the stag, were discovered in the same situation.—In a note I made at the time, 1816, it is stated that the forehead was remarkably low and narrow, and the part of the skull which contained the cerebellum unusually prominent. That these skulls were ancient there can be little doubt, but there are no sufficient data to enable us to approximate to the period of their deposition.

The bone was not mineralized, though very hard. The absence or extreme rarity of human bones in these beds of gravel and clay, or in caves that contain the remains of large land quadrupeds, is far more extraordinary than their non-occurrence in the regular strata that cover our present continents.

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way enter into strata composed almost entirely of organic remains. Beside, the strata now deep under the dry ground, are filled chiefly with the remains of marine animals; nor do we generally find these animal remains confusedly aggregated; different genera or species occupy particular strata, or are associated with certain genera or species of the same class, and never with others. It is therefore evident that they were not brought into their present situations by vast inundations, and buried under the earthy matter which a subsequent inundation cast over them. Neither could zoophytes, fish, or large reptiles, or the inhabitants of bivalve or univalve shells, have lived and flourished in the midst of solid stone. We are therefore led to the conclusion, that each stratum which contains these organic remains was once the uppermost covering of the globe, and that the animals for the most part lived and died near where their bones or shells are now found, and were covered by successive depositions of strata, in which following races of living beings flourished, and in like manner left their remains.

Animal or vegetable substances are found imbedded in rocks, and are more or less impregnated with mineral matter, and hence have been called petrifactions. The process of petrifaction consists in the infiltration of mineral matter into the pores of bone or vegetables. In some instances the animal or vegetable matter has been almost entirely dissolved or removed, and the mineral matter so gradually substituted, as to assume the perfect form of the internal structure either of the plant or animal.

The process of petrifaction may be more rapidly effected than has generally been supposed. In the year 1817 I paid a visit to

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from a person who had lived in the family part of the time, I questioned the old butler respecting it, and he fully confirmed the truth of the story. It is much to be regretted that extraordinary facts relating to the natural history of animals should not be recorded immediately when they occur, otherwise they are soon forgotten, or are intermixed with fabulous additions which destroy the entire credit of the account. A few years after the death of the butler, I enquired of Mrs. Colonel Beaumont, the present highly intelligent possessor of the mansion, whether any written narrative of the above circumstance was preserved in the family; but she told me that she had never heard of it, as the fact occurred during her infancy.

the celebrated Dr. Jenner, at Berkley, who informed me that he had made several experiments upon recent bones, by burying them in the dark mud from the lias clay: in less than twelve months the bones became black throughout, and when dry, they were harder, heavier, and more brittle than recent bone, and the surface was shining. The specimens which he showed me, presented the same appearance as the fossil bones in the lias clay. The effect was probably produced so speedily by the presence of the sulphate of iron, and other saline ingredients with which that stratum abounds. As this stratum is the most remarkable of all the secondary series, for the large animal remains which it contains, particularly of the saurian or lizard order, and as the bones are frequently covered with crystals or incrustations of pyrites, I will venture to hazard a conjecture respecting the manner in which these crystals, or incrustations of pyrites, or sulphuret of iron, are formed. The stratum before mentioned, contains sulphate of iron or green copperas in solution. I suppose that the carbon in the animal matter had decomposed the sulphuric acid and the oxide of iron, and that the sulphur and iron in their nascent state had united, and formed the sulphuret of iron or pyrites. I was led to this conclusion by reading an account by Mr. Pepys, of some mice which had by accident been immersed in a jar containing a solution of sulphate of iron: how long they had lain there was unknown; but the remains were partly covered with small crystals of pyrites, which could have been formed only in the manner above suggested. The stone surrounding the organic remains in the lias, I have observed to be considerably harder than the other parts of the same stratum. The organic remains of zoophytes and shells in limestone are generally harder than the stone in which they are imbedded; and on this account, when the stone has been exposed to the atmosphere a long time, the organic remains rise above the surface.

Organic remains are generally coloured by the strata in which they are imbedded; in roe-stone, chalk, and the upper fresh-water limestones, they approach to a yellowish or brownish white; in lias, bituminous shale, and dark limestone, they incline to black;

and the shells in bituminous shale are sometimes filled with bitumen in a fluid state. In the strata above chalk, the bones and shells retain their original constituent parts very little changed; in chalk, and all the strata under chalk, the organic remains are more or less completely impregnated with mineral matter. The outer crust or shell of many chalk fossils is calcareous, and the internal part filled with flint. In some cases we meet with an internal cast formed in the cavity of a crustaceous animal, and the external covering has disappeared: in other instances, the shell or crust of the animal has formed a mould in the stone, into which mineral matter has been subsequently infiltered, and has thus made an external cast.

It is particularly deserving of attention, that some animal remains contain the most delicate fibres and spines, perfect and unbroken: this proves that the mineral matter in which they are incrusted, was deposited in a finely comminuted state, and in a tranquil sea. In some instances the most delicate shells are regularly arranged in the same position in which the animals lived and died, while the animal remains in the strata above or below them are broken and confusedly aggregated together. The most remarkable instance of this kind I have ever observed, occurs at Westbury Cliff, on the northern bank of the river Severn, about seven miles below Gloucester. It is a low cliff, nearly perpendicular; the lower part is composed of what is generally called red marle, over which are the lower beds of lias-limestone and clay. A few yards above the junction of the lias and red marle, there is a thin stratum of dark micaceous stone, entirely filled with bones and the teeth of the shark and animals of the saurian or lizard tribe, broken and intermixed in the greatest imaginable disorder. Near the upper part of the cliff, not many feet above the stratum filled with bones, there is a thin stratum of whitish argillaceous limestone, called white lias, which is filled with the most delicate minute bivalve shells, all arranged in the same position, without any intermixture with shells of other species.

It is facts like these that are particularly deserving of the attention of the Geologist, as they mark in a striking manner the conamined, we may infer that some of the rocks of this class constitute the foundation rock of every country. We have no means of ascertaining that the similar rocks of distant districts were formed at the same time, nor can we be certain that the rocks called Primary have not once contained organic remains that were destroyed during the process by which they acquired their present crystalline structure. We may however, with apparent probability, infer that their formation was prior to the existence of animals or vegetables on our planet in its present state, because the rocks which immediately cover them contain almost exclusively the organic remains of the lowest class of animals, which are considered as forming the first link in the chain of animated beings.

On this account these rocks have been called by the German geologists *transition* rocks, from the supposition that they were formed when the world was passing from an uninhabitable to a habitable state. *Transition* or *intermediate rocks* are generally less crystalline than the primary; they containing occasionally organic remains of the lower classes of animals, and also fragments of rocks of the preceding class. They are frequently interposed between rocks of the primary class, and those more generally called secondary, and often partake of the character belonging to both. The rocks of the primary and transition class are the principal repositories of metallic ores, but in Europe they contain few saline or inflammable minerals.* In South America, according to Humboldt, sulphur and bitumen exist in considerable quantities in rocks denominated primary.

Rocks of the transition class are not universally interposed between the primary and secondary rocks, for in some situations the transition series are entirely wanting: thus in passing from Lyons to Clermont in the centre of France, I observed the regular coal strata resting upon a bed of sand, clay, and rounded stones, which immediately cover granite.

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* Except we comprise coal strata in the transition series.

Secondary Rocks.—The lower series are almost all distinctly stratified; they consist chiefly of sandstone, soft argillaceous slate, called shale, and beds of coal and ironstone. Many of the secondary strata of this class abound exclusively in the fossil remains of vegetables, analogous to ferns, palms, and reeds ; while the rocks in the former or transition class, contain exclusively the remains of marine animals, they occur principally in limestone. This change in the nature of the fossil remains in the two classes of rocks, indicates an important change in the condition of the globe, prior to the deposition of the lower series of secondary strata. The transition rocks were evidently formed under the sea, some of the beds being almost entirely composed of the exuviæ of madrepores and encrini, while the vegetable remains in the secondary strata would appear to indicate that they had grown in marshes or fresh-water lakes, covering the surface where the sea had formerly flowed.

The upper series of secondary rocks indicate another most important revolution of the globe. The prevailing rocks of this series are stratified limestone, with beds of clay, shale, and sandstone interposed. The organic remains in these strata are chiefly those of marine animals, but of different genera and species from those in the lower rocks. It is in rocks of this series that we first meet with remains of animals of a higher class, which possessed a brain and spinal marrow ; but these vertebrated animals are all of the oviparous order, such as fish, or the saurian or lizard tribe. Some of these saurian animals were of immense size, greatly exceeding in length and bulk any saurian animals now existing.

Another important fact respecting the upper series of secondary strata, is, that they appear to have been formed not only under different circumstances from the lower, but after a long interval, during which the surface of the globe had been much fractured and displaced ; for the upper series do not lie regularly upon the other, and parallel with them, but they cover the edges of the lower strata unconformably.

To make this better understood, suppose a number of books to be laid regularly upon each other, and the lowest volume to be tilted up so as to give an inclined position to the whole, if we then take other books and place them horizontally, or nearly so, on the upper edges of the inclined volumes, we may then form a distinct idea of the position of the upper series of secondary strata over the lower series. This position will be more fully described in the fourth chapter. The last of the upper secondary strata is chalk, a rock well known in the south and south-east parts of England, though entirely wanting in the north-west and in Scotland.

Tertiary Strata—comprise all the regular beds that have been deposited subsequently to the chalk strata, on which they frequently repose. It was formerly supposed that tertiary strata were very limited in extent, and were confined to a few districts in Europe; recent observations, however, prove that strata of this class cover considerable portions of the surface in various countries, though there are other countries in which they are entirely wanting. Tertiary strata are the last formed or uppermost of all the regular rock formations. They consist chiefly of clay, limestone, and friable sandstone: the lower series of these strata contain numerous marine shells, while some of the middle and upper strata contain shells resembling those found in our present rivers or in fresh water lakes. The most remarkable fact respecting the tertiary strata is, that some of them contain numerous bones of quadrupeds of the class Mammalia, but these for the most part belong to genera and species which no longer exist upon the earth.

Volcanic and Basaltic Rocks—have been either ejected from volcanoes, or poured out in a state of fusion from rents and openings on the earth's surface. They cover in an irregular manner the rocks of the preceding classes. In some situations the melted mineral matter has taken a columnar form in cooling; in other situations it fills vast fissures, called by miners—dykes. Basaltic rocks are very common in the northern part of our island.

Diluvial and Alluvial.—Considerable portions of the surface of the ground are in many countries covered with thick beds of sand or clay, and fragments of rock and loose stones, more or less rounded by attrition: in some situations these have evidently been transported from a vast distance, for frequently no rock similar to the fragments occurs within a hundred miles, or more, of the place where they are deposited. They indicate the action of mighty inundations, which have swept over the face of our present continents. The French have given to these depositions the name of *terreins de transport*, a name which defines them precisely, and comprises both diluvial deposits formed suddenly by mighty irruptions of the ocean, and alluvial deposits formed by the gradual deposition of sediment at the mouths of rivers or in lakes.

The classes of rocks above enumerated have their appropriate mineral productions, and, with the exception of rocks of the first class, their appropriate organic remains; and it would be as useless to search for regular beds of common coal in the primary rocks, as it would be to search for metallic veins or statuary marble, in the tertiary strata.

I shall proceed to elucidate the situation of the different classes of Rocks in England, by a reference to the outline map, Plate 6.

If we trace a waving line A A A from the south-west of Dorsetshire to the county of Durham, it will form a striking geological division of England: all the land on the east of this line is composed of the upper secondary and tertiary strata, in which neither metallic veins nor regular beds of mineral coal are found. The tertiary strata, lie over the upper secondary within the parts bounded by the letters *o o o o.* On part of the eastern coast of Yorkshire and Linconshire there is a submarine forest about seventeen feet under the present high-water level. This forest appears to have extended eastward, as stumps of trees and roots may be seen at low-water at a considerable distance from the coast.

West of the line A A A there is an important change in the mineral productions; from thence to the line C C C the lower secondary strata appear, and most of the principal coal districts in England occur within the lines A A A and C C C. It is further remarkable, that few if any regular metallic veins are found in this division. The lower secondary strata are also continued west of the line C C C, through the midland and northern counties, but rocks of the transition series occasionally occur in this part of our island. A very extensive coal district occurs in that part of South Wales bordering the Bristol Channel. On the east of the line C C C it may be remarked, that the strata generally incline or dip to the south-east; west of this line they are more irregular, and dip in various directions.

West of the part composed of the lower secondary strata, and coloured green, we meet with rocks of the primary and transition classes, in which metallic ores occur; they constitute the alpine parts of England, passing through Cornwall and Devonshire, into North Wales, and the north-west parts of Yorkshire and Lancashire, and through Westmoreland and Cumberland, into Scotland. This part is coloured red; rocks of the primary class chiefly occur in the parts distinguished by dark lines.

Near the centre of England, at Charnwood Forest in Leicestershire, and at the Malvern Hills in Worcestershire and Herefordshire, the primary rocks pierce through the secondary strata, and compose two small districts of primitive country surrounded by secondary strata. Also in the counties of Derbyshire and in the West Riding of Yorkshire, and part of Cumberland and Westmoreland, rocks of transition or mountain limestone rise to a considerable elevation from beneath the secondary strata, which occur east and west of them; some of these limestone mountains are rich in metallic ores. Along the line E E, beds of rock-salt and the principal springs of brine are situated.

It must be kept in mind when observing this map, that the tertiary strata lie upon the secondary, and the secondary upon the transition and primary rocks. Now, if the tertiary and secondary strata had both extended to the western counties, it is obvious that we could have had no knowledge of the existence of the lower series but by boring or sinking through the upper series; and the aggregate thickness of these, exceeds the power of the miner to pierce through. The tertiary strata, however only cover a part of the secondary, and the secondary do not cover the whole of the lower series; so that in travelling westward, we come immediately upon the lower strata in succession, as they rise from underneath each other; for, as I before observed, the general inclination or dip of the beds is towards the south-east. The action of the sea upon our coasts and cliffs has exposed to view the succession of the different rocks and strata in many parts of our island, and has enabled us to obtain a correct knowledge of their thickness and direction, and of the organic remains peculiar to each series.

Before concluding the present chapter, let us take a view of some of the more striking appearances, which afford demonstrative evidence that great changes have taken place in the relative level of the present continents, and that the ocean has in former ages rolled its waves over what are now the most elevated parts of the earth. Many proofs of this exist in our own island, and in various parts of the world.

The calcareous or limestone mountains in Derbyshire, and Craven in Yorkshire, rise to the height of about two thousand feet above the present level of the sea. They contain through their whole extent fossil remains of zoophytes and marine animals, but more abundantly in some parts than in others. Particular species occupy almost exclusively distinct beds, and in some situations the whole mass appears a compact congeries of mineralized organic remains. Over these vast beds of ancient limestone occur a series of sandstone strata and shale, containing almost exclusively remains of mineralized vegetables associated with beds of coal. Over this series we meet with other calcareous strata, containing remains of fish and enormous reptiles of the saurian or lizard tribe, intermixed with numerous species of bivalve and univalve shells, but of different genera or species from those living in the present seas. Again, in the uppermost or tertiary strata, we meet with bones and teeth of land quadrupeds of the class Mammalia, some of which belong to unknown genera, and nearly all to unknown species. Among these are the bones of large animals, as the mastodon, the elephant, the rhinoceros, the hippopotamus, and the gigantic tapir. These large animal remains occur chiefly in beds of clay or gravel, or in caves. In the latter situation they are abundantly mixed with bones of smaller quadrupeds, of which the species no longer exexist in England.

The calcareous mountains of the Jura, and the outer range of the Alps, contain beds filled with the remains of marine animals, many of which I have examined, and found to be similar to those in the secondary strata in England. In the Alps they occur at the height of from six to eight thousand feet. Similar phœnomena are observed in the calcareous mountains of the Pyrenees ; and according to Humboldt, organic remains occur in the Andes, at the height of fourteen thousand feet. The distinct characters of the animals found in the upper and lower beds in these mountains, as well as in those of our own country, prove that they were not brought into their present situation by any sudden inundations, which would have mixed different orders of animals together. The beds which contain exclusively the remains of animals of the same species, must have remained for ages under the ocean ; for these animal remains often compose nearly the whole substance of a bed of limestone of great thickness, as is the case with the beds of encrinal limestone in Derbyshire, and the limestone called coral-ragg at Steeple Ashton.

The fossil remains of animals not now in existence, entombed and preserved in solid rocks, present us with durable monuments of the great revolutions which our planet has undergone in former ages. We are carried back to a period when the waters of the ocean have covered the summits of our highest mountains, and are irresistibly compelled to admit one of two conclusions,— either that the sea has retired and sunk far below its former level, or that some power operating from beneath, has lifted up the islands and continents, with their hills and mountains, from the watery abyss, to their present elevation above its surface.

These organic remains present also undeniable proofs of another fact equally interesting. Every regular stratum in which they are disseminated, was once the uppermost rock, however deep it may be below the present surface, or with whatever rocks it may now be covered. This inference is not the less conclusive, whether we suppose that the animals lived and died where their remains occur, or whether they were aggregated and carried by marine currents into their present situation. Hence we learn that the secondary strata were formed in succession over each other, and thus these fossil remains preserve the records of the ancient condition of our planet, and the natural history of its earliest inhabitants. The unknown causes by which zoophytes and different genera and species of testaceous animals, of reptiles, vegetables, and mammiferous quadrupeds were buried in different strata have operated in succession at distant intervals of time; for we do not find the remains of different classes confusedly intermixed together, except in beds of clay or gravel, near the surface, or in fragments of various rocks which have been broken down and subsequently united. Bones of vertebrated animals, or such as had a brain and spinal narrow, have never been found in the lower strata; nor have the bones of the large mammiferous quadrupeds ever been discovered below the chalk. Hence we acquire a perfect certainty, that the different beds which form the crust of our planet, were deposited in distant epochs, and under different conditions of the globe. The animal remains in some of the strata are so delicate, and so regularly deposited, that we can have but little doubt that the animals lived and died tranquilly where their remains are now found: in other strata below or above, the remains are broken, and the animals appear to have perished by some sudden convulsion.

If the bones of man, or of mammiferous quadrupeds resembling existing species, have casually been found with fossil remains peculiar to the lower or more ancient strata, I believe a careful examination of all the circumstances would generally explain the apparent anomaly. I shall state a remarkable fact of this kind, which came to my knowledge when engaged in a mineralogical examination for the Earl of Moira, in the vicinity of vulsions which the surface of the globe has at different periods undergone.

The stratum with aggregated bones of saurian animals appears again, on the other side of the Severn, at Aust Passage, where the junction of the lias and red ground may be also observed; but I could not discover any trace of the white lias bed with the bivalves, similar to those at Westbury Cliff.

Some of the more delicately constructed animals, and the fish whose bodies are found entire, imbedded in stone, appear to have been instantaneously destroyed and enveloped in mineral matter, before the putrefactive process could commence.*

In tracing the different animal remains that occur in the lower, the middle, and the upper strata, the circumstance most worthy of notice, is the first appearance of any of the different divisions and classes of animals, and of the orders, genera, or species belonging to each division. In the luminous arrangement by Baron Cuvier in his *Règne Animal*, all animals are distributed, according to their organization, into four grand divisions—*Vertebrated, Moluscous, Articulated, and Radiated.*

1st, *Vertebrated.*—Animals which have a skull and spine containing the brain and the principal trunk of the nervous system, commonly called the spinal marrow: they have red blood. There is some analogy in the construction of all animals of this class, even in species the most remote; as man and the lowest species of fish.

2nd, *Moluscous.*—Animals with no internal skeleton; the muscles are attached solely to the skin, which is in many species covered with shells. The nervous system and viscera are composed of detached masses, united by nervous filaments; they appear to possess only the senses of taste and sight, and many species want the latter; but they have a complete system of circulation, and particular organs for respiration. All animals covered either by bivalve or univalve shells belong to this class.

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* In the Museum at the *Jardin de Plantes* in Paris, there is a large specimen of two fossil fish, which are supposed to have been destroyed and covered with mineral matter, when one of them was in the very act of swallowing the other; but an inspection of the specimen inclined me to infer that the two heads had been pressed together, by the incumbent weight of stone deposited upon them.

3rd, *Articulated.*—To this class belong insects and worms: their nervous system consists of two long cords, ranging along the body, and swelling out in different parts into knots or ganglions.

4th, *Radiated*—comprises all the animals which were by former naturalists called zoophytes, or animal plants, as the corallines, &c. which were long mistaken for marine vegetables. In animals of this division, the organs of sense and motion are disposed circularly around a centre or axis. They have no distinctly marked nervous system, and the traces of circulation in many species can scarcely be discerned. Many of the animals in this division have no power of loco-motion, as madrepores and encrinites. Others, as the echinus, possess a very complex organization, and the power of moving from place to place on their spines, which serve them for feet.

In describing the order in which organic remains belonging to each of these grand divisions are distributed through the different classes of rocks, it will be more convenient to begin with the lowest.

Radiated Animals, such as encrini and madrepores, have left their remains abundantly dispersed through rocks of the transition series; many of the strata appear almost entirely composed of their mineralized exuviæ, but generally in a broken state. The chain coral occurs occasionally in transition limestone. Other genera of radiated animals occur in the more recent formations of limestone, but seldom in sufficient abundance to compose nearly the whole mass of a stratum. This is the more remarkable, as coralline animals are forming extensive calcareous rocks in our present seas. Some genera and species of radiated animals which abound in transition rocks, have not left their remains in any of the upper strata. Hence it might be inferred that they were and had long been extinct; in some instances the inference is not correct: the *Madrepora stylina*, so common in transition limestone, is entirely wanting in the secondary and tertiary strata:

but a living animal of this species has recently been discovered in the South Seas. The Pentacrinus, which is chiefly distinguished from the Encrinus by its pentagonal stem and branches, makes its first distinct appearance in the lias; but is not frequently met with in the upper strata, and disappears entirely in the uppermost formations: hence it was long supposed that the species was extinct. A living Pentacrinus has recently been discovered in the West Indies, and its stem and branches in a perfect state have been sent to this country.

The genus echinus makes its first appearance in the midst of the secondary strata; and various species are continued into chalk, which abounds with remains of this animal in high preservation. It may be remarked, that scarcely any calcareous stratum exists abounding in marine organic remains, in which remains of some species of radiated animals may not be found.

Articulated Animals.—Insects are rarely found with other organic remains, but one of the oldest inhabitants of the globe appears to belong to this division. It has in England been called the Dudley fossil, from being first noticed in the transition limestone near that town; it has also been called the Trilobite, from the three parallel divisions of the body. Some of the species have been vulgarly named the fossil Butterfly, from a resemblance to the form of the wings and body of that insect. It appears to have been a crustaceous aquatic animal, with ranges of transverse ventral fins somewhat similar to those under the belly of a lobster. The largest species of these animals is found in the slate quarries at Angers in France. A perfect specimen which I purchased at the sale of the late Faujas St. Fond, measures seven inches in length, the breadth is two inches; the body has taken the flattened form, common to almost all fossils found in slate: it scarcely rises more than one third of an inch above the surface of the slate; the other side of the slate contains a perfect impression or mould of the form of the animal. To this species Guettard has given the name of *Ogyges*, from its occurrence among the most ancient rock formations that contain vestiges of organic life.

The remains of insects are extremely rare in all the secondary strata in England, except in that anomalous formation at Stonesfield, where the supposed elytra of coleopterous insects, or rather impressions of them, occur. In the same strata, fossil crabs are also found; and I have a specimen from the oolite near Kingscote in Gloucestershire, which appears to be part of the claw of a crustaceous animal. In the soft beds in the tertiary strata, the remains of crabs are more common: but of all the four divisions of the animal kingdom, the Articulated has supplied the smallest number of organic remains: this may be caused chiefly by the fragile nature of their bodies in most of the species, and their peculiar modes of existence.

Moluscous Animals.—Shells, chiefly bivalves, occur in the transition series; but the species are not numerous in this class. A few species of chambered univalves occur, but the individuals of each species are far from numerous. One or two species of unchambered univalve shells are said to have been found in transition limestone; they are, however, of extremely rare occurrence. In the secondary strata the number of species and of individual bivalve shells is greatly increased; and about the middle of the series, chambered spiral shells, nautilites and ammonites, become abundant; and various species are continued into the chalk.

The trochiform or top-shaped spiral shells first make their appearance in the strata above the lias; and different genera of univalve unchambered shells appear, and become abundant, in these strata. In the transition and secondary strata, all the genera and species of moluscous shells are commonly supposed to differ from those of animals at present existing. In the tertiary strata the number of genera and species, particularly univalves, is greatly increased; and all the genera and many of the species, bear a close resemblance to, if they are not indentical with, living genera and species.

Vertebrated Animals.—Remains of the lowest class, fish, are extremly rare in transition rocks; but they appear decidedly in the magnesian limestone over the coal strata; and in the argillaceous limestone and clay called lias, the entire bodies of fish are frequently found well preserved. In this stratum, which is the most remarkable for the abundance and variety of its organic remains, we first meet with bones of reptiles of the saurian or lizard class, of immense size; but different from any existing genera, and evidently inhabitants of the ocean, being furnished with paddles instead of feet.* In the upper secondary strata, between the lias and chalk, the remains of saurian animals, closely allied to living species of crocodiles and lizards, are fully developed; they had feet, and were evidently amphibious. Of the saurian animals discovered in this series, that called Iguanodon, discovered by Mr. Mantell at Cuckfield in Sussex, is the most remarkable for its size; the length exceeding seventy feet, and the thickness of the body being equal to that of the elephant. It is supposed to have been herbivorous. It closely resembles in structure the Iguana, a native of America and the West Indies.

In the whole of the transition, the lower secondary and upper secondary rocks, no remains of the highest class of vertebrated animals, the mammalia, are found, nor even of birds; unless the strata at Stonesfield belong to this series, and form the only known exception. It can scarcely however be supposed, that during the formation of all the secondary strata, no part of the earth's surface was dry land; and if dry land really existed, it might be tenanted by warm blooded quadrupeds; and if so, their bones might have been carried down by rivers or inundations into the ancient seas or lakes, at the bottom of which were deposited the strata containing the remains of amphibious reptiles. It is therefore truly surprising that an intermixture of the bones of terrestrial and marine animals should be of such rare occurrence.

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* Sir Everard Home, and particularly the Rev. W. D. Conybeare, have elucidated the osteology of these remarkable animals. The Ichthyosaurus, or Fish Lizard, was an animal intermediate in its organization between the crocodile, the lizard, and fish; with paddles long broad and flat, instead of feet, designed for moving rapidly through the water: the orbits of its eyes are enormously large. It was an inhabitant of the sea:—four species have been ascertained, some of which are of immense size. The Plesiosaurus, another genus more nearly approaching the organization of the lizard, is distinguished from all oviparous quadrupeds by its slender neck; which is longer than its body, and is composed of no less than thirty vertebræ, exceeding in number those in the neck of the swan. This animal is supposed to have swam on the water, with its neck arched to dart on its prey. The *Testudo ferox*, living in the rivers in Florida, is somewhat similarly constructed; it hides itself in reeds, and darts out its head suddenly to seize birds and other animals. There are five species of the Plesiosaurus, some of them were more than twenty feet long. Remains of flying lizards have been discovered in a fossil state in Germany.

Vertebrated animals of the class *Birds* have left a few of their remains in the tertiary strata, particularly in the beds of gypsum near Paris: but the bones of birds are so rare, that the existence of any species which might properly be called fossil was long doubted. Cetaceous animals allied to the whale and seal, have left very few vestiges of their former existence in any of the strata.

Vertebrated land animals of the highest class, the *mammalia*, have left numerous remains in some parts of the tertiary formations, but more frequently in beds of ancient gravel or clay, than in the solid strata. Cuvier has ascertained the existence of fossil bones belonging to about seventy species of mammiferous quadrupeds. Nearly forty of these are of extinct species, and several of them belong to extinct genera. A very considerable number of the large fossil bones belong to the different genera and species of the order named by Cuvier *Pachydermata*, or thick-skinned non-ruminant animals; as the elephant, the mastodon, the tapir, the hippopotamus, the rhinoceros, and the paleotherium. As these bones are very abundantly found in many countries in Europe, it proves that the animals were natives of temperate climates. The known existing species of the above genera are all inhabitants of countries near the equator. The fossil elephant, that was once a native of Europe, according to Cuvier differed as much from the Asiatic or the African elephant, as the horse differs from the ass. Bones and teeth of extinct species of carnivorous quadrupeds are generally found in caverns, intermixed with other species, in a broken state. Since the time that these fossil bones have been studiously examined by those naturalists who have attended to comparative anatomy, no vestiges of human remains have been discovered; nor have any of the bones of the animals which approach nearest to man in structure, the

Quadrumanes or monkeys, been yet found with those of the more ancient inhabitants of the globe. The vast diluvial beds of gravel and clay, the upper strata in Asia, have however not yet been scientifically explored; and both sacred and profane writers agree in regarding the temperate regions of that continent as the cradle of the human race.*

Vegetable fossil remains are not so highly interesting as those of animals; but they present us with many phenomena, which are extremely curious. A brief outline of them is here given; and a further account of vegetable remains will be found in the chapter on the Coal Strata. Bituminous or vegetable matter occurs in some of the slate rocks of the transition series, and increases in quantity in the soft slate or shale of the secondary strata, where we find portions of plants well preserved and in great abundance. Vegetable remains are also found abundantly in some of the sandstones in the secondary strata, and also in the beds of clay of the tertiary strata. The fossil remains of plants are rarely if ever found in the lower calcareous strata; nor could we expect to meet with them there, as these strata were evidently formed at the bottom of ancient seas. If such remains occasionally occur in the upper calcareous strata, it is reasonable to believe that they had been carried by rivers into ancient seas or lakes, and intermixed with the remains of aquatic animals that

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* It has been conjectured by some persons, that the bones of man are more fragile and perishable than those of land quadrupeds; but this is contrary to experience; for it has been well observed by Cuvier, that the bones of men, left on the field of battle with those of horses, are as well preserved as the latter, making allowance for the difference of size. Neither is there any essential difference in the chemical constituent parts of human bone from that of other animals of the class mammalia. Dry bones, according to Berzelius, contain as under:

	Human Bones.	Human Teeth.	Ox Bones.	Ox Teeth.
Cartilage,	33	—	33	3.5
Phosphate of lime,	51	85.3	55	81
Carbonate of lime,	11.5	8	9	7
Fluate of lime,	2	3.2	3	4
Phosphate of magnesia,	1.2	1.5	2	3
Soda and muriate of soda,	1.3	2	2	2

perished there. In this manner also may we account for the appearance of vegetables in ancient strata or beds of clay containing marine shells and the teeth or bones of fish. The vegetable remains in the transition and secondary strata belong chiefly to monocotyledonous plants, analogous to palms, reeds, or ferns. Some of the latter are of gigantic size: and it has been observed, that none of the fossil plants that have been examined, belong to species existing in Europe, but many of them are supposed to resemble species at present flourishing in tropical climates. In the upper or tertiary strata we meet with arborescent plants. In some situations we find that the woody part is only partially mineralized; but in other situations, in the upper strata, fossil vegetables are more completely mineralized than in the lower strata, being apparently changed into flint, or silicefied: but even in this state, when the silicefied substance will strike fire with steel, and cut glass, the form of the minutest vegetable fibres may often be perceived, and some trace of the original vegetable principles may be discovered by chemical analysis.

OBSERVATIONS.

The author has attempted in this chapter to give a succinct account of the Geological distribution of fossil organic remains, belonging to the four grand divisions of the animal kingdom. This he conceives will interest the learner, for whose use it was chiefly intended, more than a detailed account of the remains of the genera or species supposed to be peculiar to different rock formations. With respect to fossil conchology, he is inclined to believe, that the attempt to identify the strata of distant countries by the isolated occurrence of any particular species of shell, has been carried further than a sound induction from facts or analogy would warrant. His opinion on this subject, given in the 2d edition of this work, he will here insert. "It may be doubted whether the occurrence of similar organic remains, is sufficient to identify strata in distant parts of the globe; for could we admit that strata are universal formations, and extended from the frozen to the torrid zone, it seems more than probable, that the animals which lived on any one particular stratum, would be of very different species in different latitudes."—We know so little respecting the forms or habits of the animals classed by the conchologist, that we are far from certain, whether many shells which he regards as belonging to different species or even genera, are not mere varieties of form, occasioned by difference of age or situation. Such a change is ascertained to take place by age in shells of the genus *Cyprea.*

In animals like the moluscæ, which have no internal skeleton to determine their form, the construction of the external shell may probably admit of considerable variation under a change of circumstances. Few conchologists excepting M. D'Avilla have made accurate observations on the living animals inhabiting oceanic shells. His interesting work, entitled '*L'Histoire Naturelle eclaircie dans une de ses parties principales, la Conchologie et augmentée de la Zoomorphose ou Representation des animaux à coquilles avec leurs explications,*'—presents us with some truly extraordinary forms of moluscous animals, of which we could not have had a remote notion from the mere study of the shell.

In strata belonging to one formation and in adjacent districts, the existence of certain shells, whether we regard them as distinct species or as varieties, may be of use in identifying any particular bed;—and in distant countries where we find the same remarkable species of shell associated with any other remarkable species in considerable numbers, it may serve to identify a particular rock-formation, where the mineral character of the rock may be very different from that in which the observer has been accustomed to meet with them. The occurrence of a considerable number of gryphea, the *Gryphea arcuata,* in a bed of blue clay in the mountains round the Lake of Annecy in Savoy,—served the author as a key to discover to what formation the calcareous strata belonged, when their mineral characters would have indicated a more ancient series.

CHAPTER III.

ON THE MINERAL SUBSTANCES THAT COMPOSE THE CRUST OF THE GLOBE; AND ON THE STRUCTURE OF ROCKS.

The constituent Elements of the simple Minerals that compose Rocks.—The physical Characters of simple Minerals composing Rocks.—Explanation of the Terms employed in describing the internal Structure of Rocks, and the external Structure of Mountain Masses.

THE most careless observer can scarcely fail to notice, that the mineral substances which occur on the surface of the globe differ from each other in density, hardness, colour, and other sensible qualities. Indeed the different varieties of stone appear at first so numerous as to render it difficult to become acquainted with them :—but, however numerous these varieties may be thought, the simple minerals which compose rocks or strata are very few ; and the elementary substances of which each of these minerals is formed, are still fewer.*

The elementary substances of which the solid matter of our globe is composed, are the *Earths—silex*, *alumine*, *lime* and *magnesia.* The *Metals—iron* and *manganese.* The *Inflammable Principles—carbon* and *sulphur;* and the *Alkalies—potash*, *soda* and *lithia.—Muriatic* and *Phosphoric Acid* occur also in the mineral kingdom:—the newly discovered earths and alkalies and metallic ores cannot be regarded as forming essential constituent parts of rocks, they occur chiefly in veins. The first five substances above enumerated compose nineteen parts in twenty of the known solid matter of the globe. The Earths when pure are infusible, except at an intense heat; they are nearly insoluble in water at the common temperature: when pure, they are white or colourless. Though the earths are infusible when pure, if they are combined in certain proportions, they may be fused with facility at a comparatively low temperature.

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* The mineralogist and the geologist consider those minerals as simple and homogeneous, which present no difference of qualities to our senses throughout the mass, although the chemist may discover that such minerals are composed of two or more elementary substances. Thus limestone or marble is regarded as a simple substance, though chemistry has discovered that it contains in every hundred parts—lime 57 parts, and carbonic acid 43. It is the latter which is expelled from it by burning,—a process which is well known to make the stone lighter and to render it caustic, in which state it is called quicklime. Nor do the researches of the chemist end here: the two substances quicklime or pure lime, and carbonic acid, are themselves compounds; the former, lime, is a compound of a metallic substance called calcium, united with oxygen; the latter, or carbonic acid, is composed of oxygen and carbon or charcoal.

Silex, or *Siliceous Earth*, exists nearly pure in large masses, forming minerals and even entire rocks; as rock-crystal, quartz-rock, and flint: it communicates a great degree of hardness to all rocks or stones in which it enters in a large proportion. Such stones are denominated Siliceous; they resist the point of a knife, or scratch glass. In its combinations with other earths Silex appears to act as an acid. More than one half of the crust of the globe is composed of siliceous earth either pure or combined. In some thermal waters, siliceous earth occurs either in a state of minute division or in solution; and the waters of the boiling springs or geyzers in Iceland deposit siliceous incrustations of considerable thickness.

Alumine, pure argillaceous Earth,—Lat. *argilla*—Fr. *argille*,—is a substance which in a mixed state is well known; but pure unmixed clay is one of the rarest substances in the mineral kingdom. This earth is soft, smooth, and unctuous to the touch; it strongly absorbs water; where it exists in the proportion of thirty per cent, it communicates in some degree these properties: such rocks are called argillaceous; they generally contain a notable portion of iron, which appears to have a greater affinity for this earth than for any other.*

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* Though alumine or pure clay communicates a soft quality to most stones of which it forms a principal constituent part, a very remarkable exception to this is offered in adamantine spar and the sapphire, which nearly equal the diamond in hardness. Klaproth, one of the most laborous and eminent chemists of the present age, has analysed

Lime,—Lat. *calx.*—Fr. *chaux*,—is a well known earth combined with carbonic acid, in which state it forms limestone, marble, and chalk: these differ from each other only by different degrees of hardness, or of crystallization. Mountains composed of lime are denominated calcareous. When lime is united with sulphuric acid, it forms the stone called gypsum, which is softer than limestone, and does not, like it, effervesce with acids. Calcareous earth mixed with common clay forms marle.

Magnesia has rarely been found pure in a native state. It enters into the composition of some of the primary rocks, to which it generally communicates a soapy feel, a striated or striped texture, and sometimes a greenish colour. It occurs also in various limestones in different proportions.

Iron appears to be more abundant than magnesian earth; it forms a constituent part of numerous rocks and stones; to it they most frequently owe their colour; the earths when pure are white. Iron when in combination with the earths is like them an oxide, or a metal united with oxygen. To the presence of iron, the increase of specific gravity in all stones or earthy minerals may be attributed, if it much exceed 2.5, or approach 3: in other words, if they are nearly three times heavier than an equal bulk of water. Gems and the earths barytes and strontian are exceptions, but these never form entire rocks. The presence of iron not only increases the weight, and darkens the colour of numerous rocks and stones, but is one principal means of their decomposition, for iron exists in stones in two states of oxygenation, as the black or the red oxide; and when the former is exposed to air and moisture, it absorbs a greater portion of oxygen, and is converted into a brown ochrey incrustation, which peels off, and exposes a fresh surface of the stone to a similar process.

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these stones: the former contains 90 parts in the 100 of pure clay; the latter 95 parts in the same quantity. "What a high degree of cohesive power (he observes) must nature command, to be able to transform such a common substance as clay (aluminous earth) into a body so eminently distinguished and ennobled as the sapphire by its hardness, brilliancy, and its resistance to the action of fire, of acids, or the effects of all-destroying time!—*Klaproth's Essays.*

Manganese, in a state of oxide occurs in a few rocks, to which it generally communicates a dull reddish colour inclining to purple, and a peculiarly dry and burnt-like appearance.

Sulphur, though found in considerable masses, cannot by itself be regarded as a constituent part of rocks; but when it is combined with oxygen forming sulphuric acid, it unites with lime and forms the well-known mineral gypsum or plaster stone.

Carbon or *Charcoal* enters as a constituent part into many of the slate rocks, to which it generally communicates a dark colour, it forms also regular beds of considerable thickness, being the principal constituent part of coal. Carbon combined with oxygen, forms carbonic acid or fixed air, which is combined and solidified in all limestone rocks in a proportion exceeding two-fifths of the whole weight. As carbon exists in such a large proportion in even the oldest limestones, we may regard it as a constituent element, and not as a substance derived from the vegetable kingdom. For whence did the vegetables themselves derive their carbon?

Potass and *Soda.*—These alkalies occur in minerals which compose parts both of primary and volcanic rocks; but the proportion is so small that they would scarcely deserve the attention of the geologist, did not the latter alkali, exist in such abundance in the waters of the ocean and in rock salt. Pure sea salt or rock salt contains nearly 53½ parts of soda 46½ muriatic acid or chlorine.

Muriatic acid combined with soda is the only state in which this acid forms a constituent part of any rocks we are yet acquainted with; except in some volcanic rocks, where it may be regarded as accidental.

Phosphoric Acid combined with calcareous earth, is a principal constituent of animal bones: it occurs also in a few limestone beds, which are supposed to have derived Phosphoric acid from the decomposition of animal matter: this acid is of very rare occurrence in the mineral kingdom.

The above elementary substances, either separately or combined, form all the simple minerals of which rocks are composed.

A knowledge of these minerals and their different intermixtures and combinations, can be learned only by an examination of specimens; they are, however, far from being numerous, and a short description of each is necessary in an introductory treatise.

The most important simple minerals composing rocks are quartz, felspar, mica, talc, chlorite, hornblende, serpentine, limestone, and slate.

Quartz is one of the hardest minerals of which mountain masses are composed: it gives plentiful sparks with steel; it breaks with a smart stroke of the hammer; the surface of the fracture in crystallized quartz is conchoidal, in uncrystallized, splintery;—the lustre is vitreous. Crystals of quartz, or rock-crystals, as they are commonly denominated, have different degrees of transparency; the blue varieties are amethysts. The most common forms of the crystals are six-sided prisms terminated by six-sided pyramids, or two six-sided pyramids united, forming a dodecahedron whose faces are isosceles triangles. Uncrystallized quartz is seldom transparent, most frequently translucent, but sometimes opaque. Its colours are various shades of white, grey, brown, yellow, red, and green. It yields a phosphorescent light and peculiar odour when rubbed. Quartz is composed of siliceous earth combined with a very small portion of alumine. It is infusible when unmixed; but with alkalies it melts easily, and forms the well known substance called glass. It is not acted upon by any acid except the fluoric. Quartz exists in veins intersecting mountains, and it sometimes forms large beds, and even entire mountains, which are composed of this mineral in grains united without a cement, called granular quartz. Fragments or crystals of quartz are common in compound rocks. Grains of quartz form a principal constituent part of most sandstones. The milk-white pebbles in gravel are composed of quartz. Flint, chert or hornstone, opal, chalcedony, and agate, are different modifications of siliceous earth, which in their chemical composition differ little from quartz. Combined with a large portion of alumine and iron, quartz loses its translucency and passes into jasper, which forms beds in primitive mountains, and is said to compose the substance of entire ranges of mountains in Asia.

Felspar or *feld-spar* (a name received from the Germans) is a constituent part of numerous rocks. It is hard in a somewhat less degree than quartz, and is more easily broken. It is laminar, or composed of thin laminæ or plates, by which it may be generally distinguished from quartz. The crystals are most commonly four-sided or six-sided prisms, whose length is greater than the breadth. It has a shining lustre. The colours are white, gray, milk-white, yellowish, or reddish white, sometimes inclining to green. The red passes through various shades, from a pale to a deep red. Crystallized felspar is translucent. It may be melted without the admixture of alkalies, and forms a glass more or less transparent, which quality it derives from the lime or alkali that composes part of its constituent ingredients; but different specimens of this mineral vary, according to the analyses of the same chemist.

Silex - - - - - - -	63 — 74
Alumine - - - - - -	17 — 14
Potash - - - - - - -	13 —
Lime - - - - - - -	3 — 6
Oxide of iron - - - - - -	1 —
Loss - - - - - - -	3 — 6

Others give the proportion of silex 46, alumine 24, lime 6.

The existence of potash or the vegetable alkali in felspar, is a fact deserving particular attention.[*] It may be owing to this circumstance that felspar is so frequently observed in a soft or decomposing state, although its hardness is little inferior to that of quartz when undecayed. Those felspars which are durable are probably free from potash. Felspar is sometimes uncrystallized and compact, in which state it is classed by the French mineralogists with petrosilex or hornstone. Compact felspar, however, differs from hornstone, the latter being infusible without the addition of alkalies.

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[*] It has recently been discovered, that in some of the felspathic rocks, soda occupies the place of potash, and gives a slight change to the crystalline form: this variety some mineralogists are desirous of making a new species, and have proposed to give it the name of Cleavelandite; but geology and mineralogy are already too much burdened with unmeaning terms, and if a new name must be introduced, that of felsparite would at once convey an idea of its approximation to felspar.

Mica derives its name from the Latin *micans*, glittering. It is known as the substance called Muscovy glass, and has a splendid lustre. It consists of very thin leaves or laminæ, which may be easily separated with a knife. The plates are elastic, by which it may be distinguished from the mineral called talc. The thin plates are transparent. The colours of the thick plates are yellow, gray, blackish green, white, and brown. The surface may be scratched with a knife: it melts into an enamel with the blowpipe; it is rarely met with crystallized.

Talc nearly resembles mica in appearance. The plates are flexible, but not elastic: it is much softer than mica, and is infusible; its colours generally incline towards green; but it is sometimes a silver white: it has a soapy feel. *Chlorite*, which is nearly allied to talc, derives its name from *chloros*, the Greek word signifying green. Talc and chlorite pass by insensible gradations into each other, and in this state they supply the place of mica in most of the granitic rocks that I have examined in the vicinity of Mont Blanc. Cholorite is of a darkish dull green colour; it has a glistening lustre; its structure is minutely foliated; it is soft, and rather unctuous. The constituents of these three minerals are,

	Mica.	Talc.	Chlorine.
Silex	50	62	41
Alumine	35	2	6
Lime	1		1
Magnesia	2	27	40
Oxide of iron	6	3	10
Water and loss	6	6	2

but these proportions vary in different specimens.

Hornblende, to which the French give the name of *amphibole*, forms a constituent part of many rocks, and appears to connect the primary with those which are of volcanic origin. It is of a black or dark green color: it is heavier but less hard than quartz or felspar; it may be scratched with a knife, and the colour of the streak is a light green: it yields a bitter smell when breathed upon, and melts easily into a black glass. Common hornblende is often confusedly crystallized; it sometimes forms entire mountains, or slaty beds in mountains, and is very commonly met with, in granular pieces, as an ingredient in compound rocks: when it becomes more abundantly and minutely disseminated in them, it forms what are denominated trap rocks, whose origin has greatly divided the opinions of geologists. Hornblende and the rocks to which it is most nearly allied contain as under:

	Hornblende.	Basalt.	Obsidian or volcanic glass.	Lava.
Silex	42	44	72	49
Alumine	8	16	12	35
Magnesia	16	2		
Lime	9	9	sometimes	4
Oxide of iron	23	20	2 with manganese.	12
Soda		4	6 with potash.	
Manganese	1			
Water and loss				

Another mineral substance called *serpentine*, from its spotted colours resembling the serpent's skin, will afterwards be described as forming entire rocks: it differs in composition from hornblende by having a larger portion of magnesia and less iron; it may perhaps be regarded as an intimate combination of hornblende with talc or chlorite. Its component parts, as given by different chemists, are as under:

Silex	45	29	45
Alumine	18	23	
Magnesia	23	34	33
Iron	3	4	14 with a trace of alumine.
Lime			6
Water and loss	11	10	8

From these analyses it is evident that the specimens vary in their component parts; in some, the proportions are almost the same as in hornblende; in others, they more nearly agree with talc and chlorite.

Limestone, *Carbonate of lime*, however various in external appearance it may be, is, if pure, essentially composed of 57 parts of lime and 43 carbonic acid; but in some rocks the limestone is intermixed with magnesia, alumine, silex or iron. The specific gravity of limestone varies from 2.50 to 2.80. All limestones may be scraped with a knife. They are infusible; but when impure by an intermixture with a portion of other earths, they vitrify in burning. All limestones effervesce when a drop of strong acid is applied on the surface, and they dissolve entirely in nitric or muriatic acid. The specific gravity, hardness, and effervescence with acids taken collectively, distinguish limestone from all other minerals.

Crystallized Carbonate of Lime, *Calcareous Spar*, occurs crystallized in a great variety of forms; but the crystals break easily with the stroke of a hammer, and the fragments are always rhomboidal.

Vast mountains and extensive strata of limestone cover a large portion of many countries. The varieties of limestone will be described, as the rocks occur in the primary or secondary series. The different appearance of statuary marble and chalk is well known to every one. They are only different modifications of limestone, and are chemically the same. Magnesian limestone, sometimes called Dolomite, possesses most of the physical characters of common limestone, but contains various proportions of magnesia: it will be described when we treat of the rocks with which it is associated.

Gypsum or *Sulphate of Lime*, is far less abundant than Carbonate of Lime, but it forms in some situations beds of considerable thickness and extent. Gypsum is generally of a colour inclining to white, and is sometimes snow-white. Common gypsum has a laminated or granular structure, and is sometimes compact. It is much softer than common limestone, and may be scratched with the nail: it does not effervesce with acids. Crystallized gypsum has the properties of common gypsum; it is frequently called selenite. The constituent parts of gypsum are lime 32.7, sulphuric acid 46.3, and water 21. A variety of gypsum which has no water in its composition, and hence called anhydrous, occurs in beds in the Savoy Alps; it is there combined with siliceous earth. It is much harder than common gypsum, and even than common limestone. The specific gravity of common gypsum varies from 2.16 to 2.28, that of anhydrous gypsum is from 2.80 to 2.90. Gypsum under the name of plaster stone is a mineral generally known.

Slate, improperly called by some geologists Clayslate, and by the old geologists Argillaceous Schistus, is well known,—at least the common variety used as roofing-slate, which may be regarded as the purest form of this mineral.

The prevailing colours of slate are bluish or greenish gray; it has a silky lustre. Slate rocks have frequently a distinct slaty structure, and may even be split in two directions, which have an acute angle with each other; but some slate rocks have a compact structure, and will not admit of splitting; slate yields to the knife, it is fusible into a black slagg. The composition of slate is various; indeed by many geologists it is not regarded as an homogeneous rock. Its composition has been given as under: silex 48, alumine 23, manganese 1.6, oxide of iron 11.3, oxide of manganese 0.5, potass 4.7, carbon 0.3, water 7.6. The quantity of carbon increases in the upper formations of slate, and it passes by a greater admixture of carbon into a soft dark slaty bed, denominated shale by the English miners. Slate is a very extensive formation, composing entire mountains in many alpine districts.

Basalt and compact lavas are classed by some mineralogists with simple minerals, but they are composed of three or more simple minerals closely united:—they will be afterwards described.

Some of the minerals here enumerated compose entire rocks; other rocks are composed of an intermixture of two or more simple minerals, either cemented together by another mineral substance, or the minerals are crystallized and united without a cement. The different modes in which simple minerals are found united together in rocks have given rise to the following terms.

Granitic, composed of grains or crystals united without a cement, as in granites and some sandstones.

Porphyritic, composed of a compact homogeneous rock, in which distinct crystals or grains are imbedded. The compact stone is called the base, and sometimes the paste. The base of some porphyritic rocks is granitic; in this case some of the crystals are much larger than the rest.

Amygdaloidal, containing rounded cavities filled with mineral matter of a different kind.

Breccia is composed of angular fragments of rocks cemented together.

Pudding-stone consists of rounded stones imbedded in a paste.

Fragments of stone broken from *simple rocks* display the structure of the internal parts. The face of the broken part is called the fracture. This internal structure may be denominated the mineral structure, and is either

Compact, without any distinguishable parts or divisions—or

Earthy, comprised of minute parts resembling dried earth.

Granular, composed of grains.

Fibrous, composed of long and minute fibres.

Radiated, when the fibres are broader and flattish, and diverging.

Lamellar or *Foliated*, composed of minute plates laid over each other.

Porous, penetrated by pores.

Cellular or *Vesicular*, when the pores swell into rounded cavities like bladders, as in some lavas.

Slaty or *Laminar*, composed of straight parallel thin plates, or laminæ.

The structure of *compound rocks* may also be *Slaty*.

The external structure of rocks *en masse*, or considered as mountain masses, is as distinct from their internal mineral structure as the shape of a building from that of the bricks or stones of which it is composed, though this distinction has been generally overlooked. The external structure of rocks, as forming mountain masses may be

Stratified, or stratiform.

Tabular, or in large plates.

Columnar.

Globular, or in spherical masses.

Massive or *Indeterminate*, which includes all unstratified rocks that have no determinate shape.

Stratified mountains or rocks are those which are composed of layers of stone, laid over each other, and divided by parallel seams like the leaves of a closed book. In these seams or partings, which divide the strata, there are frequently thin laminæ of soft earthy matter; but sometimes the surfaces of the upper and lower stratum are so closely joined, that it requires a considerable force to separate them. These layers are denominated strata; they extend through the whole mountain or mass, their length and breadth being much greater than their thickness. If the thickness of any stratum exceed two or three yards, it is more usually denominated a bed; and if it lie between beds of stone of a different kind, it is said to be imbedded. Strata always decline or dip down to some point of the horizon, and of course rise towards the opposite point. A line drawn through these points is called the line of their dip; another line drawn at right angles to this, marks the course along which the strata stretch out to the greatest extent;—it is called the line of bearing. If a book be raised in an inclined position, with the back resting lengthways upon the table, the leaves may be supposed to represent different strata; then the direction of the leaves from the upper edges to the table will be the line of dip, and their direction lengthways the line of bearing; and the angle they make with the table will be the angle of inclination. Strata are, however, sometimes waved or bent in both directions, and are frequently broken; which makes it difficult to ascertain their true position.

It is generally supposed that stratified rocks were formed by the motion of water, which arranged them in succession over each other in the same manner as the muddy waves of the ocean deposit their contents in regular layers upon the shore. This mode of formation is called mechanical deposition. It has also been erroneously though generally believed, that all rocks divided by parallel seams into separate layers, are stratified in the direction of the seams or partings, and this error has led to much confusion in describing rocks; this will be more fully explained in the following chapter.

The *tabular structure* consists of parallel plates of rock, separated by regular seams. This structure has often been confounded with stratification: it appears to be the result of crystallization, and is closely allied to the columnar structure.

The *Columnar* or *Prismatic structure* is peculiar to certain rocks, but occurs chiefly in the basaltic and volcanic class. Thick beds are divided into columns or prisms, which are most generally pentagonal. They sometimes form vast ranges of natural columns; as at Staffa, the Giants' Causeway in Ireland, and in many volcanic countries. Sometimes the prismatic structure may be observed forming detached groups of columns and prisms, as represented in the group of columns on Cader Idris, Plate 6. A group of basaltic columns of similar form, and equally perfect, was observed by the author on the side of the volcanic mountain called Gravenaire, in Auvergne, at a small distance from the crater.

The *Globular structure* consists of globular masses either detached or imbedded in rocks of the same kind; they are frequently composed of concentric layers.

The terms *Massive* or *Indeterminate*, may be applied to all unstratified rocks that have no regular divisions. Many of the primary rocks, such as granite, porphyry, and serpentine, occur in masses of enormous thickness, which are broken by irregular fissures in every direction. Thick currents of lava, which have filled up hollows or valleys, are also indeterminate, as might be expected from their mode of formation. Sometimes rocks of granite and porphyry, and also of compact lava, present either a tabular or columnar structure; but the structure is seldom so regular as in basaltic rocks.

CHAPTER IV.

ON STRATIFICATION, AND THE RELATIVE POSITION OF ROCKS.

The Principles of Stratification explained.—Various Appearances presented by plain Strata.—Appearances presented by curved Strata, and Errors respecting them.—Distinction between Strata.—Seams and Natural Fissures or Cleavages.—On the conformable and unconformable Positions of stratified and unstratified Rocks.—The Intersection of stratified Rocks by Valleys explained.—Longitudinal Valleys.—Transverse Valleys.—Lateral Valleys.—On the Elevation of Mountains and Mountain Chains.—On the Direction of Mountain Chains in the new and old Continents.—On vertical Beds in Mountains.—On the apparent Devastation in Alpine Districts.—On the Passages in the Alps called Cols; and Observations respecting their Formation.

When we have ascertained what are the most common or prevailing rocks in a part of any country, and observed that any one stratum or rock which attracts our attention is in that part of the country invariably covered by a peculiar rock or stratum of a different kind, or invariably covers any particular stratum; we hence learn that there is a certain order of superposition, and we naturally feel desirous to know whether the same order is observable in every country where similar rocks occur. Thus in the vale of Thames round London, there is at the depth of a few feet under the surface, a dark-colored clay called London Clay; and if we bore through this clay, we shall find its average thickness to be nearly 300 feet; but when we have pierced through this clay, we invariably come to chalk; and were we to continue to bore in the chalk, after piercing through many hundred feet of that rock, we should come to a stratum of sand or sandstone filled with green particles, and hence called Green Sand.

The observer who had confined his researches to this part of the country only, would form a very erroneous conclusion were he to infer, that the outer crust of the globe was invariably composed of London Clay, Chalk, and Green Sand. But wherever similar beds occur together, they lie in the same order of superposition over each other. Thus the London Clay is never found under the Chalk, or the Green Sand.

But it is not always necessary to bore through the upper beds to ascertain this order: for the different strata scarcely ever occur in a flat or horizontal position; they generally rise in a certain direction, and come to the surface, as represented in Plate 1, fig. 1. Now by travelling in the direction of the strata from A to B, we come upon the outer edges 1 2 3, and may trace their order of succession as they rise from under each other. In ravines and the escarpments of mountains, and in the cliffs on the sea coast, we are also enabled to trace the order of position and succession of rocks. But to do this with tolerable correctness, we must have an accurate knowledge of stratification in all its various possible forms. However simple the principles of stratification may at first appear, this knowledge when applied to practice is not of such easy attainment as some may imagine, and for want of it, Geologists of considerable eminence have fallen into the most egregious errors. A knowledge of Stratification is indeed of far greater importance to the practical geologist, than an acquaintance with the minutiæ of Mineralogy or Conchology.

Though the word Stratum in its original language and by general acceptation, in speaking of rocks, denotes a bed, it is convenient to restrict the term bed to strata of considerable thickness; for such beds are often subdivided into several distinct minor strata, and we cannot well describe a stratified stratum.

When a series of strata of a similar rock are arranged with occasional strata intervening of rocks of another kind, which recur in different parts of the series, they are regarded as having been formed nearly at the same epoch, and under similar circumstances; and such series are called by geologists *Formations.* Thus the strata of marle accompanying chalk, with the strata containing nodules or layers of flint, are, together with the whole series of chalk strata, denominated the chalk formation. In order to obtain a distinct idea of stratification in its simplest form, let the young geologist take a piece of pasteboard or thin wood,—

say twelve inches square: let him divide it in the middle into two equal planes, each twelve inches in length and six in breadth. Place one of these planes flat on a table with the ends facing the north and south; the sides will of course be at right angles, and face the east and west. Now if one of the sides be tilted,—say the western side,—we may suppose the pasteboard plane to represent a stratum rising to the west and dipping eastward. The lengthways direction of the plane is called the *line of bearing;* and the declining direction is called the *line of dip*, which is at right angles to the line of bearing. The angle at which the stratum rises above the horizontal line or level is called the *Inclination.* Suppose the western edge of the pasteboard plane is raised above the table, forming with it an angle of thirty degrees; then we say the direction of the stratum is north and south, its dip east, its rise of course west, and its angle of inclination thirty degrees. Simple as this appears, geologists of considerable eminence have made the most palpable mistakes in defining stratification. It has been said correctly, that the line of dip being always at right angles to the direction or line of bearing, when the dip is given, the direction is known: but when it is further said, that if the direction is given, the line of dip is given also, the assertion is erroneous; for let the above plane of pasteboard be again laid flat upon the table in the same direction, due north and south; but instead of tilting up the western edge, if we tilt up the eastern, we shall then have the same line of bearing as in the first instance, but the dip will be west instead of east.

It sometimes happens that a stratum without varying its direction may dip two ways in the same mountain, like the sloping sides of the roof of a church, or the letter Λ reversed. Place the two planes of pasteboard in a north and south direction, and raise them so as to make the upper edges meet; we shall then have the line of bearing north and south as before, and the dip east on one side and west on the other. The limestone strata at Dudley Castle Hill dip on each side of the hill as above described.

Whatever may be the inclination of a stratum, its true thickness is measured by a line perpendicular to the upper and under surface.

If we take a number of similar planes of pasteboard of different colours, and lay the undermost a little inclined, and place another plane upon it, with the upper edge about an inch or more distant from that of the under stratum, and again lay the others in succession in the same manner; the uncovered ends of the planes will rise from under each other like a number of slices of bread and butter laid on a plate. These uncovered edges will represent the outcrop or crop of the strata; and it will be perceived how we may obtain a knowledge of an under stratum, without sinking or boring, merely by crossing a country in the line of the rise or dip of the strata. When strata are arranged in this manner, they are said to be in a conformable position. (Plate 1. fig. 1.) It will naturally be inquired, whether the strata absolutely terminate where we find their outcrop? In some instances this is the case; but frequently the strata are bent or broken in the line of their rise, and the same stratum may crop out in one place and appear again further on in the line of its rise, as represented Plate 1. fig. 2. We must be particularly attentive to this circumstance, otherwise we may mistake the true position of a stratum, and describe it as one much lower in the series we are examining. In some instances we come suddenly to the termination of a whole series of strata, as in descending the Cotswold Hills into the Vale of Severn; the limestone called Roe-stone, of which they are principally composed, is not found on the other side of the valley, nor in any part of England to the north-west of it. Has this limestone ever extended further? and if it have extended further, by what cause has it been removed? These inquiries will be adverted to in a following chapter.

To return to our pasteboard planes, arranged as before described, with the edges rising from under each other in the conformable position. If we take another series of planes, and lay them flat over the outcropping edges of the conformable series, we shall then have the unconformable position represented, Plate 1.

fig. 3. Now the strata that cover the lower stratified class in England occur in this position; and the following important inference may be drawn from it, namely, that the under stratified rocks had been formed, and their strata broken and raised up, at a period which must have preceded the formation of the upper series by a considerable interval. For the lower series were evidently solidified, and afterwards in many instances broken; and the fractured edges of the strata levelled, before the unconformable strata were deposited upon them.

The most common error which persons commencing the study of geology are liable to make, is in mistaking the apparent for the real inclination of the strata. Plate 1. fig. 4. will render this more intelligible than any description. It represents a portion of a stratified mountain, of which the strata have a considerable dip to the east. If the escarpment or section be made in the line of bearing, the strata will appear to range from north to south, without any rise or dip, and would be described by a young observer as being horizontal. But if an opening or section be made on the side parallel to the line of dip, as at *c*, *c*, the true inclination will be seen. Any section made in an oblique direction to the line of dip will cause the inclination to appear less than the true one, and the line of dip will appear to vary from the true one. The chances therefore are very great against the natural section made in a mountain presenting the true dip and inclination of the strata. Another error which a person who does not attend to the dip and direction of the strata may fall into is, mistaking an under for an upper stratum. Suppose a hill to be covered with vegetable soil, and a quarry or pit was made in it near the bottom, as at *a*, Plate 1. fig. 1. and the stone was discovered to be sandstone: suppose another pit was sunk near the summit at *b*, which cut into limestone; it might be supposed that the limestone lay over the sandstone stratum, when it is in reality below it. The young observer, who has not a clear notion of this, may be said not yet to have passed the *pons asinorum* of the geologist.

In calcareous mountains of vast magnitude, as those in the Swiss and Savoy Alps, the enormous beds of limestone are often intersected by regular seams, which cut through the whole bed in a direction nearly perpendicular to that of the true strata seams, or make very oblique angles with them. These partings or seams are sometimes nearly vertical, when the strata are almost horizontal. The cliffs and escarpments of these mountains being lofty and much exposed to the action of the atmosphere, the vertical seams enlarge, and are often more conspicuous than the strata seams; hence without great attention, the observer may describe the strata of a mountain as being perpendicular when in reality they are nearly horizontal. To add to the difficulty, it very frequently happens that a calcareous deposition like a coat of plaster covers the face of a rock: this has been formed by moisture running over the surface, and depositing calcareous particles upon it. This deposition sometimes conceals the stratification seams as completely as a coat of plaster covers the rows of brick in a building. The vertical seams or partings are also sometimes open, and sometimes have formed parallel ridges, which efface the appearance of the strata seams in one part of a rock, but not in the other; and in such instances we have apparently a mountain mass in which the strata are partly horizontal and partly vertical. See Plate 1. fig. 5. Inattention to this circumstance I am convinced has sometimes deceived the eye of M. Saussure, one of the most diligent and accurate of observers.

The modes of stratification we have been considering are those of plane strata; but in many situations, particularly in the Alps and the Jura chain, the strata are curved and bent round the mountains, encircling them like a mantle. The ravines and escarpments according to the position in which the sections have been made, present the most varied forms of stratification in the same mountain. In one part, the strata will seem to rise almost vertically; in another, to be nearly horizontal; and in a third, to be deeply curved; and this will depend much on the relative position of the observer, whether he be placed on one side or in face of the escarpment. Suppose a transverse section be made through a mountain in the direction *a*, *b*, (Plate 1. fig. 6.) it would show the true position of the arched strata: but if we suppose the side of the mountain *c*, *d*, to be removed, an observer placed at E would see the face or escarpment on that side, with the edges of the strata lying horizontally, and might describe them as horizontally stratified, were he to view no other part of the mountain. In some situations the fracture made in the arched stratification is much broken; and we have on the side of the same mountain the appearance both of horizontal and greatly inclined stratification. An instance of this occurs near the Lake of Bourget in Savoy. Plate 2. fig. 1. represents the appearance of strata on the side of a mountain, which has the arched stratification before described; but the outermost strata, instead of enfolding the whole mountain, only cover the southern side, and are broken off at the summit in a line nearly parallel with it; and their edges present the appearance of horizontal strata, *a*, *a*. Lower down the mountain, part of the under strata have fallen off in a sloping direction, and their projecting edges present at a distance the appearance of highly inclined strata. This may be further illustrated by taking a half cylinder, or, for want of that, a thick book; and opening it a little, place it with the edges upon the table, and the back uppermost; cover the book or half cylinder with a number of folds of paper of different colours,—these will represent arched strata. Cut away the outermost folds along the back, and take away the other half; the edges of the paper will represent those of the upper strata, and their position will appear to be horizontal. Cut away the corners of the under sheets a little behind each other, so that the edges of each coloured sheet may be visible; and these will represent the appearance of highly inclined strata, and have frequently been mistaken for such. The young geologist may greatly facilitate the study of stratification, by laying coloured planes of any soft and yielding substance over each other, and inclining them in various positions; then let him make sections in different directions with a knife, and also carve out hollows representing valleys, cutting through inclined strata at various angles with the line of dip and line of bearing;

by this means he may gain a more correct idea of the varied phœnomena of stratification, both in mountains and valleys, than the most elaborate descriptions can convey.

The appearance of vertical and horizontal strata in the same rock (as represented Plate 1. fig. 5.) is of very rare occurrence in this country; such a position can be effected only by a fault, which had thrown the strata on one side into a vertical position. The appearance represented in the above figure, is however, frequently to be observed in the calcareous strata adjoining the Alps, where the vertical divisions are not true strata, but seams or partings, which sometimes are so considerable, as to efface the true strata seams; this has hitherto been little understood, and has been the source of much error in geological descriptions. The reader must suppose the horizontal lines to be continued through the vertical seams.

The appearance of contorted stratification (Plate 2. fig. 5.) is an optical illusion. The strata originally infolded the mountain like the coats of an onion, but have partly fallen off, one behind the other, leaving waving edges, (like the letter S,) overlapping each other. Original inequalities in the general curvature of the beds, may have occasioned the strata to break off in this manner. The Montagne de Tuille near Montmelian, (which is drawn in the third volume of Saussure's *Voyages dans les Alpes*,) offers, I conceive, an instance of this apparent contortion, which Saussure considered as almost inexplicable. I examined the mountain fróm various stations, and am persuaded, that the contortions are only apparent, and are not like the real contortions, which the lower beds of transition limestone in this country so frequently present.

The strata of secondary rocks belonging to the same formation generally preserve the same thickness for a considerable extent, and are arranged conformably over each other, except in situations where the regularity of the strata has been disturbed by rents or fractures. In these secondary conformable strata, the order in which they succeed each other indicates their relative ages; but this rule cannot be extended to all classes of rocks.

No inference can at first appear more legitimate than this; "The rock which supports another must be older than that which rests upon it, if their original position has not been changed." But this conclusion, when examined with attention, will fairly admit of doubt with respect to those rocks which are crystalline like the primary. These were formed by chemical affinity from a state of solution, or by crystallization from a state of fusion:—if by the latter mode, all the different beds may have been arranged at the same time, and the upper and lower rocks may have a cotemporaneous origin. If a mass of melted matter from a furnace cool slowly, the internal and external parts will vary both in their physical and chemical properties; but it cannot, on this account, be said that the lower part is older than the upper. In those rocks which have been subjected to external agency, as in sand rocks which contain fragments that have been rounded by water, their situation evidently proves that they were formed after the rocks on which they rest.

It has been before observed, that those rocks which contain different species of organic remains, separated by beds or strata in which no such remains occur, must have been formed in succession over each other, and probably at very distant intervals of time. This inference appears to me conclusive, nor can it be invalidated by the crystalline arrangement and cleavage of some of those rocks.

Rocks of the primary class frequently cover each other in an order which, viewed on a grand scale, may be said to be conformable; but the different rocks in each class are generally of such vast and irregular thickness, that their order of succession is often not easy to trace: beside, some of these rocks pass by a change of structure into each other, and their line of junction or separation can seldom be observed. Viewed, however, as composing mountain chains, the more general arrangement is represented, Plate 3. fig. 1. on which granite or the foundation rock is marked *a*, gneiss *b*, mica slate *c*, common slate *d*, the transition series *e*, *e*, and the lower secondary F, F. *x*, *x*, represents the position of a bed of limestone or any other rock in a mountain of slate; in this position it is said to be imbedded; and if a number of these beds occur, they are said to be subordinate.

The uncomformable position of unstratified rocks is represented, Plate 3. fig. 2. where *d* is a mass of columnar basalt, and *c* a mass of porphyry resting upon the rocks 1, 2, 3, without any conformity to the shape of the lower beds. Whatever theory we adopt respecting the formation of rocks, we must admit that the superincumbent rocks in this situation are of more recent origin than those which they cover; the lower must have been hard and unyielding, when the upper were thrown upon them. If a thick stream of lava, as frequently happens, were to flow over a range of conformable rocks, filling up the cavities and inequalities of the surface,—when it became hard by cooling, it would form a bed of superincumbent uncomformable rock. Such instances are common in volcanic countries. Very extensive ranges of rocks and mountains occur in this position in various parts of the world, not only covering the primary, but the secondary rocks. These will hereafter be described, under the name of porphyry, sienite, and basalt. They frequently assume the columnar structure, and sometimes form vast ranges of natural pillars; as at Staffa one of the Hebrides, on the north coast of Ireland, in Iceland, Sicily, and many volcanic countries.

Having described the position of both stratified and unstratified unconformable rocks, it may be proper to state that the latter rocks occur, covering both primary, transition, secondary, and tertiary strata: many of those which cover the secondary and tertiary, seem evidently to have been the products of subterranean fires; and even those which cover the primary and transition rocks, bear a close affinity to volcanic rocks. If we admit that our loftiest ranges of mountains were elevated by the expansive force of central fires, this power acting upon an extensive portion of the globe, might be ages in upheaving the incumbent surface, which would continue to rise until vast fissures were made, through which the subterranean melted matter would be thrown over the mountains and plains then existing, and form the superincumbent rocks of basalt, porphyry, and sienite, that seem to be so nearly allied to volcanic products. While one part of the surface was rising, another part would sink, and form a new bed into which the waters of the ocean would gradually retire.

According to Humboldt, the extraordiny eruptions by which new islands have been formed since the period of authentic history, have been preceded by a swelling of the softened crust of the globe. At Kamerni, the new island made its appearance above the sea twenty-six days before the smoke was visible. "Every thing indicates that the physical changes of which tradition has preserved the remembrance, exhibit but a feeble image of those gigantic catastrophes which have given mountains their present form, changed the position of the rocky strata, and buried sea-shells on the summit of the higher alps. It was undoubtedly in those remote times which preceded the existence of the human race, that the raised crust of the globe produced those domes of trappean porphyry, those hills of isolated basalt in vast elevated plains, those solid nuclei covered with the modern lavas of the the Peak of Teneriffe, of Etna, and Cotopaxi." *Humboldt.*

To these great catastrophes, and the mighty force of vast inundations which have swept over our present continents, must we ascribe the inequalities of the earth's surface, the elevation of mountains, the excavation of valleys, which have broken the continuity of strata, and removed the broken parts into distant countries.—It is not my intention in the present chapter to enter on the subject of the formation of valleys; it will be reserved for a subsequent part of the volume; but it may be useful to state to the geological student, that all stratified mountains are only parts of extended strata, with which they were once united.

This will be more distinctly understood by consulting Plate 4. fig. 1. which is intended to represent the general rise of the strata from Sheffield in Yorkshire to Castleton in Derbyshire, intersected by the valley through which the river Derwent flows.

The town of Sheffield, fig. 1. is built over coal strata, which rise towards the west, and disappear in that direction about five miles from Sheffield (2.) Here the under rock makes its appearance (3,) which is a bed of coarse gritstone, more than one hundred and twenty yards in thickness, forming the summits of all the mountains as you advance to the vale of Derwent (4.) The grit-rock rests upon a thicker bed, of a different kind, composed of slaty sandstone, represented (5.) On the western side of the valley, this rock exists only as a cap or covering on Whin-Hill, a lofty mountain, marked (6.) Two miles further west the grit-rock disappears, and the slaty sandstone which is the base of Whin-Hill forms the summit of the celebrated Mam Tor, or the the shivering mountain. The mountain limestone (7) here makes its appearance as the base of Mam Tor, and further west the same limestone forms entire mountains. The difference observable in the rocks east and west of the Derwent is owing to the general rise of the strata in the latter direction.

It is here obvious that Whin-Hill, though it appears an isolated mountain, is only a portion of the thick beds of gritstone, and slaty sandstone, which form the hills on the other side of the valley.

When valleys take the same direction as that of a range of mountains, they are called *longitudinal valleys*; when they cut through a range of mountains, they are called *transversal valleys*; in the latter case, the strata on each side are most generally prolongations of the same beds.

The small valleys which open into a larger valley nearly at right angles to it are called *lateral valleys*. In some rare instances, a valley is formed by the bending of the strata, which make a trough as represented Plate 1. fig. 2.

Mountains, except those formed by volcanos, are seldom isolated masses rising from a plain, but they form groups, or are ranged together in a certain direction, and compose long and lofty ridges, denominated mountain chains. Lower ranges of mountains, running in the same direction as the principal range, and separated by valleys of greater or less width, may be observed accompanying almost all very lofty mountain chains. This fact appears to indicate the operation of a powerful elevating force, acting in one direction along a certain line, and decreasing in intensity as the distance from each side of this line increases: but this action does not appear to extend with equal force on both sides of the line; for the smaller chains parallel to the great chain are seldom so numerous on one side of it as on the other. The principal mountain chain, if very large, has its sides furrowed by small lateral valleys, and has not been unaptly compared to a back-bone or spine, with diverging ribs.

Mountain chains traverse continents and islands, and appear to constitute the skeleton on which they are formed. The shape of many countries and islands is evidently determined by the direction of the grand mountain chains that run through them.

The principal mountains in the old continents when viewed on a large scale may be considered as forming a mountain chain composed of numerous mountain groups, and extending in an easterly direction from Cape Finisterre in Spain, to the most eastern extremity of Asia. Various parts of this chain receive different denominations in the different countries through which they pass. The Pyrenees, the Alps, Mount Taurus, Mount Caucasus, the Altaic and the Himmaleh mountains, and the Yablonnoy mountains of Tartary which extend nearly to Beerhing's Straits, may be regarded as forming together one immense mountain chain, and dividing the northern from the southern dry land both in Europe and Asia.

In North and South America one unbroken chain of mountains runs in a northerly and southerly direction for eight thousand miles near the western side of that vast continent, and with some minor diverging chains has evidently determined the general outline of both countries. A remarkable similarity occurs in the position of the escarpments or steep sides of mountains in the same mountain range. Various opinions have been formed respecting the law which the position of the escarpments appears to follow; but I believe the rule I submitted to the attention of geologists in the first edition of this work will be found to approximate to the truth.

Mountain chains or ranges present the steepest declivities on the sides nearest to the sea. This is remarkably the case in the long chain of the Alleghany mountains on the eastern side of America, which are steep towards the Atlantic. On the contrary, the Stony-mountains which run near the north-west coast, and the Andés near the southern Pacific ocean, are steepest on their western side. In ranges of mountains that form the boundaries of lakes or of extensive vales, through which large rivers flow, the mountains nearest to the rivers have the steepest declivities. The largest rivers have their origin from the sides of mountains which are most inclined to the horizon, and most remote from the sea.

The beds or strata of very lofty mountains are generally much inclined, and are sometimes nearly vertical. Among these highly inclined beds, we not unfrequently observe beds of limestone containing marine shells, which must have been originally deposited at the bottom of the ocean. In some instances we meet with vertical strata, containing rounded pebbles and water-worn fragments of other rocks; these must also have been originally deposited on a surface nearly horizontal: we are therefore certain, that the present vertical position of these strata is not their original one; and we hence also learn, that all the strata associated with them in the same mountain, and having the same inclination, were raised together. We have further proof that before the epoch when this great revolution was effected, all these beds were covered by the seas then existing, and it was under the ocean that the change of position took place.

No person who reflects on the appearances presented in a mountainous district can believe that the broken and elevated beds, the peaked summits, the impending cliffs, and the immense fragments of rocks scattered in the valleys and adjacent countries, were originally created and placed as we now observe them.

The traveller who in crossing an extended desert should meet with the remains of some unknown temple, could not for a moment doubt that the broken and prostrate columns, the mutilated arches, the scattered capitals and inscriptions, had been removed by some devastating cause from their original position; nor is the proof less certain, that the rocky pavement of our globe has been broken, and its parts which were once united, widely separated from each other. Some of the phœnomena we observe in mountains were produced by the disturbing force which first elevated them; others have been subsequently effected either by vast inundations, which have swept over their summits and torn away considerable portions of the softer beds, or by the more gradual decomposition and disintegration produced by atmospheric influence; by the latter cause, the lofty and exposed peaks and escarpments of rocks are slowly wearing down.

During the two summers I passed in the Alps, I was much struck with the circumstance that all the great openings or passages over these mountains, called *Cols*, were made by excavations in beds of soft slate; and the fact I think admits of an easy explanation, but I do not know that it has been before remarked by Geologists.

If we suppose a portion of the Alps to be represented, Plate 2. fig. 2. the dotted lines above the present surface will mark the supposed original prolongation of the different beds at the period when they were raised. As the ocean, from whence these beds were raised, must have been agitated with inconceivable violence, the retiring waters would scoop out deep excavations in the softer beds of schist, and also tear off many of the vertical plates of the hardest rocks, and form the rudiments of these pyramidal peaks and aiguilles, which rise like the spires of a Gothic cathedral. Subsequent deluges, of which there are also proofs, may have further torn away portions both of the harder and softer beds; and the disintegration of the granitic aiguilles which are exposed to the influence of atmospheric agency is daily taking place, and their ruins are every day falling on the surface of the glaciers, and are carried down into the valleys: their peculiar forms are derived from their laminated structure, which disposes them to split in a vertical direction.*

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* Plate 2. fig. 2. represents the general position of the beds near the Col de Balme, and Mont Blanc; *a a a* alternating beds of sandstone and limestone; *b b* elevated beds of puddingstone, containing rounded stones and fragments of the lower rocks; *c c* soft slate, in which a passage or Col is formed; *d d d* vertical granitic beds rising in pyramidal forms, called Aiguilles or Needles.

CHAPTER V.

ON ROCKS GENERALLY DENOMINATED PRIMARY.

Classification of Primary Rocks.—Granite; its constituent Minerals.—Varieties of Granite.—Structure of Granitic Rocks.—General Appearance of Granitic Mountains.—Granitic Aiguilles.—Structure of Mont Blanc.—Principal Localities of Granite.—Situations in England where Granite is found.—Granite Veins.—On what has been denominated Secondary Granite.—On the Passage of Granite into Felspar-porphyry and Sienite.—Minerals that occur in Granite; Uses to which it is applied.

If any rocks can with propriety be denominated Primary or Primitive, they are those which are most widely spread over the globe in the lowest relative situation, and which contain no remains of organic existence. Primary rocks are supposed by Geologists to constitute the foundation on which rocks of all the other classes are laid; and if we take an enlarged view of the structure of the globe, we may admit this to be the fact,—but the admission requires certain limitations. The same causes that have produced granite and the other primary rocks in immense masses below all other rocks, have in some situations reproduced them in smaller masses, covering rocks belonging to the Transition or Secondary Classes. No systems of classification can be made so definite in the mineral kingdom, as those which relate to organic beings in the vegetable or animal kingdoms. It will however be convenient to retain the term Primary Rocks, when treating of those rocks which, according to the present state of knowledge, are the foundation rocks of every country, although some of these rocks may occasionally make their appearance in the upper formations.

Primary rocks are composed chiefly of the hard minerals, quartz, felspar, and hornblende; the minerals, mica and talc, are disseminated in smaller proportions, and limestone and serpentine occur in beds or masses, but less frequently than the above named minerals. If we refer the slate rocks to the Transition

Class, the few simple minerals here enumerated constitute nearly the whole of the mountains denominated Primary.

The structure of primary rocks is crystalline; they form the central parts of the most elevated mountain chains, and they occur at the lowest depths that have yet been explored, and are hence believed to be the most ancient of rock formations.

Werner has enumerated fourteen primary rocks: but as some of these have been found hitherto in only one place, it appears improper to consider them as distinct orders, unless we arrange every variety of rock in the same manner, and increase the number of orders indefinitely.*

The following arrangement of Primary Rocks will, I trust, be found both simple and intelligible, and as conformable to nature as the present state of our information will admit. It includes only three principal rocks as primary; granite, with gneiss and mica slate, which are nearly allied to granite, and form an incrustation over it: these never contain organic remains, and they have rarely been observed lying over other rocks in which such remains are found.

Class I.

Principal Rocks denominated Primary.

1. Granite, comprising all the varieties of this rock, and small-grained granite passing into porphyry. Eurite of the French Geologists, primitive porphyry of the Germans.
2. Gneiss or Slaty Granite.
3. Mica Slate.

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* The system of classification introduced by Werner, was formed principally from observations made in Saxony, and had great merit, as illustrating the geology of that part of Germany: but it has been objected with much reason to the general adoption of the terms he employs, that they were framed to suit a particular theory, before a sufficient number of facts had been collected to warrant its reception. Subsequent discoveries have also proved, that the different classes into which Werner has divided rocks, have not the marked and definite characters necessary to constitute a natural system of arrangement.

Subordinate Rocks which occur among Primary.

Hornblende Rock.
Serpentine.
Crystalline Limestone.
Quartz Rock.

Some of these subordinate rocks occur also among rocks of the Transition Class.*

The three principal rocks of the Primary Class,—granite, gneiss, and mica slate,—might with propriety be regarded as belonging to one formation. They are composed essentially of the same minerals varying in different proportions, and are rather modes of the same rock, than different species. They pass by gradation into each other, as one or other of their constituent minerals become more or less abundant; they alternate with each other in various situations, and may be regarded as cotemporaneous. It may, however, for the convenience of description, be proper to treat of each separately.

Rocks of the First Class.

Granite is considered as the foundation rock on which slate rocks and all secondary rocks are laid. From its great relative depth, granite is not frequently met with, except in alpine situations, where it appears to have been forced through the more superficial covering of the globe. Where granite rises above the surface, the beds of other rocks in the same district generally rise towards it, and their angles of elevation increase as they approach nearer to it. Some writers derive the name from *geranites*, a word used by Pliny to denote a particular kind of stone; others, with more probability, suppose that the name originated from its granular structure, or the grains of which it is composed. Granite is composed of the three minerals described in the third chapter,—quartz, felspar, and mica; which are more or less perfectly crystallized, and closely united together.

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* Since the publication of the first edition of this work, M. Brongniart, a celebrated French mineralogist, has proposed an arrangement in many respects similar to what I had adopted. The characters of Brongniart's first class agree with those I had before given in this work. "La première classe renfermerait les terreins dans lesquelles on n'a encore découvert aucun débris de corps organisés dont la structure est crystallisée, et dans la composition desquelles les roches granitiques proprement dites sont dominantes."—*Journal des Mines, Mai*, 1814.

The three minerals of which granite is composed vary much in their proportions in different granitic rocks; and often in specimens from the same rock the crystals are large, or small, or equally intermixed, in one part, and in another part quartz or felspar greatly predominates. Some granites are composed of small grains, and have large crystals of felspar interspersed; these are denominated Porphyritic Granites. Stones of this kind are common in the foot-pavements of London.[*]

Felspar in general constitutes by far the largest part of granite: the more common colours are white and red; it is sometimes in a soft or decomposing state, and appears earthy. In some granites the crystals of felspar are distinctly formed. Quartz generally occurs in small irregular-shaped grains, which have a vitreous lustre. The mica in granite occurs most commonly in small shining scales, which are most frequently either black, or whitish and silvery. It sometimes occurs in large hexagonal plates, but this is more commonly the case in the granite that forms veins in granitic mountains; such veins with large plates of mica are frequent near Aberdeen in Scotland. Mica readily separates or divides into thin transparent laminæ; and where the plates are very large, as in the Siberian granite, it is used instead of glass for windows. This variety is improperly called Muscovy Talc. Talc resembles mica, but is much softer. When the grains of felspar and other minerals are very minute in granite, it can scarcely be distinguished from sandstone.

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[*] Specimens of Cornish and Scotch granites are not difficult to procure in London, as they are commonly used for paving-stones. In the former the felspar is white; the mica appears like glistening scales which have a tarnished semi-metallic lustre. The quartz has a vitreous appearance, and is of a light gray colour. In Scotch granite the felspar has more commonly a reddish brown colour. The mica is not unfrequently black and splendent, and may be divided into thin scales by the point of a penknife: this distinguishes it from hornblende, which is sometimes intermixed with this granite.

Beside the three minerals, quartz, felspar and mica, which were formerly considered as the essential constituent parts of all true granite, whoever has attentively examined various granitic districts, must have frequently observed, that other minerals occupy the place of mica either in part or entirely. Thus near the summit of Mont Blanc, the granite is composed of felspar, quartz, and talc or chlorite, the latter mineral supplying the place of mica. To this variety of granite the name of Protogine has improperly been given; whereas *Talcy* or *Chloritic Granite* would at once convey a distinct idea of its nature. In some instances, hornblende supplies the place of mica, or is intermixed with it. To this rock the name of Sienite was given, because a granitic rock of this kind from Sienna in Upper Egypt, was much used by the ancients for obelisks.

The following varieties of granitic rocks are often associated with common granite in the same mountain mass, and may be regarded as cotemporaneous with it, being essentially the same rock, accidentally modified by an admixture with other simple minerals.

Common Granite.—The felspar white or red, composed of quartz, felspar and mica.

Porphyritic Granite, in which large crystals of felspar occur in a small-grained granite. The granite from a mountain near Shap in Westmoreland offers an excellent type of this.

Sienite or *Sienitic Granite*, in which hornblende, either wholly or in part, supplies the place of mica. The granite of Malvern and the Charnwood Forest hills afford specimens of this granite.

Talcy or *Chloritic Granite.*—Quartz, felspar, and talc or chlorite. Many of the granitic mountains in Savoy are composed of this granite; and loose blocks of it are scattered over the valleys and on the sides and summits of the calcareous mountains in the countries to the north and north-west of the Alps. This granite is by some writers called Protogine.

Felspathic Granite, in which the felspar is the principal ingredient, and the quartz, and particularly the mica, very rare; larger crystals of felspar occur in it. It is frequently nearly white. To this variety Werner has given the name of White Stone,—and the French, Eurite. It occurs in beds in common granite in Cornwall. In its most compact form, it becomes a porphyry, and is closely allied to volcanic rocks in Auvergne.

Granite occurs in masses of vast thickness, which are commonly divided by fissures into blocks that approach to rhomboidal or pretty regular polyhedral forms. Sometimes a columnar structure may be observed in granitic mountains; in other instances, where the quantity of mica is considerable, granite divides into parallel layers or plates, that have been mistaken for strata. Granite is occasionally found in globular masses, which are composed of concentric spherical layers, separated by granite of a less compact kind, and inclosing a hard or central nucleus. These globular masses are often three or four yards or more in diameter, and are either detached or imbedded in granite of a softer kind; this structure is not peculiar to granite.

The aspect of granitic mountains is extremely various: where the beds are nearly horizontal, or where the granite is soft and disintegrating, the summits are rounded, heavy, and unpicturesque. Where hard and soft granite are intermixed in the same mountain, the softer granite is disintegrated and falls away, and the harder blocks remain piled in confusion on each other, like an immense mass of ruins. Where the granite is hard, and the beds are nearly vertical and have a laminar structure, it forms lofty pyramidal peaks or aiguilles, that rise in enormous spires; such are the aiguilles in the vicinity of Mont Blanc, which are far more interesting, both to the picturesque traveller or the Geologist, than Mont Blanc itself. The Aiguille de Dru is perhaps the most remarkable granitic mountain at present known; the upper part or spire rises above its base nearly to a point in one solid shaft more than four thousand feet; the summit is eleven thousand feet above the level of the sea.*

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* A short description of this mountain, with a plate, is given in the 2d volume of "Travels" by the Author.

It has been observed in so many situations, that it may perhaps be regarded as a general law,—wherever granite rises high above the surface of the earth, the strata of limestone or other rocks in its vicinity rise towards it. Numerous instances of this occur in the Swiss Alps. In the higher part of the valley of Lanterbrun in the Canton of Berne, I have seen a bed of limestone in immediate junction with granite in a perfectly vertical position, like a wall built up against it.

In many of the highest mountains in the northern or Swiss Alps, granite is seen only near their bases; the summits are composed of immense beds of limestone and secondary stratified rocks. In the southern chain, or the Savoy Alps, the highest summits are granite; indeed the highest known point at which granite has been observed in any part of the world is Mont Blanc in Savoy, the loftiest mountain in Europe, rising fifteen thousand six hundred and eighty feet above the level of the sea, or nearly five times higher than any mountain in England or Wales. It was first ascended by Doctor Pacard in 1786, and afterwards by Saussure, who has published a very interesting account of his ascent. Several persons have since ascended this mountain, but Saussure is the only traveller who has given us any information respecting its structure. I shall therefore insert a brief account of his observations; they are highly interesting.—He set out from the priory of Chamouni, from whence the distance to the summit of the mountain in a direct line is not more than two French leagues and a quarter: but owing to the difficulty of the ascent, it requires eighteen hours continued labour, exclusively of the time necessary for repose and refreshment. The first day's journey was comparatively easy, the route being over soil covered with vegetation, or bare rocks. The ascent on the second day was over snow and ice, and more difficult: at four o'clock in the afternoon of the same day, Saussure and his attendants pitched their tent on the second of the three great plains of snow which they had to traverse. Here they passed the night, fourteen hundred and fifty-five toises (or three thousand one hundred yards) above the level of the sea, and ninety toises higher than the Peak of

Teneriffe. The barometer stood at seventeen inches. The next morning they proceeded with much difficulty and fatigue, arising principally from the extreme rarity of the atmosphere, which affected their respiration. The upper parts of Mont Blanc are above the limits of perpetual snow, and it is only on the sides of the nearly perpendicular peaks and escarpments that the bare rock is visible. They gained the summit by eleven o'clock A.M. "From this elevated observatory," says Saussure, "I could take in at one view, without changing my place, the whole of the grand phenomenon of these mountains; namely, the position and arrangement of the beds of which they are composed. Wherever I turned my eyes, the beds of rock in the chains of secondary mountains, and even in the primary mountains of the second order, rise towards Mont Blanc and the lofty summits in its neighbourhood: the escarpments of these beds of rock were all facing Mont Blanc, but beyond these chains were others whose escarpments were turned in a contrary direction. Notwithstanding the irregularity in the forms and the distribution of the great masses that surround Mont Blanc, and those which constitute the mountain itself, I could trace some features of resemblance not less certain than important. All the masses which I could see were composed of vertical plates (*feuillets*,) and the greater part of these plates were ranged in the same direction, from north-east to south-west. I had particular pleasure in observing the same structure in the lofty peak of granite called the *Col du Midi*, which I had formerly endeavoured, but in vain, to approach, being prevented by inaccessible walls of granite. After the second day's ascent, this lofty pinnacle was beneath me; and I fully convinced myself that it is entirely composed of magnificent plates (*lames*) of granite, perpendicular to the horizon and ranging from east to west. I had formerly been induced to believe that these plates were folded round the peak, like the leaves of an artichoke; but this was an optical illusion, when seen imperfectly from below: here, where the eye could as it were dart down into the interior structure of the mountain, the plates of rock appeared regularly parallel in a direct line. I was also" says Saussure, " particularly desirous of ascertaining whether the vertical beds were composed of the same substances at their summits as at their bases, where I had so frequently inspected them; and I am perfectly satisfied from actual examination, that they preserve the same nature through their whole extent, and are the same at the summit as below.*" *Voyages dans les Alpes*, tom. 4.

The inference drawn by Saussure, respecting the vertical position of the beds of granite that compose a principal part of Mont Blanc and the adjoining mountains, is, that they were originally horizontal, and have been subsequently elevated by some tremendous convulsion of nature. The summit of Mont Blanc, he says, must at one time have been more than two leagues under the surface. To the same convulsion he also attributes the position of the escarpments or steep sides of the rocks which face Mont Blanc for a considerable extent, and then turn from it in an opposite direction. This would be the case had the surface of the globe been broken and elevated in the manner he supposes. There is a circumstance stated by Saussure, which tends strongly to confirm, if not absolutely to prove, the truth of his hypothesis. Some of the vertical beds of rock adjacent to the granite, contain round pebbles, boulders, and waterworn pieces of the lower rocks. See observations on these beds, Chap. IV. It is impossible to conceive that those rounded fragments could have been placed in a vertical position; for, if they be really pebbles and boulders, the beds on which they occur, must originally have been nearly horizontal. Now as these beds are at present placed between others which are also vertical and in the same range, it follows that the whole have been overturned and thrown up, at a period subsequent to their formation.†

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* The extreme fatigue and exhaustion which Saussure experienced during the ascent of Mont Blanc is supposed to have abridged the life of this active and intelligent philosopher.

† An opinion has lately been advanced, that the rounded pebbles which occur in rocks are not really waterworn fragments, but original parts of the rock: but Saussure says expressly, that the boulders in the rocks near Mont Blanc are precisely similar to the boulders on the shores of the lake of Geneva. That rocks sometimes

The Himmaleh Mountains in the centre of Asia rise ten thousand feet higher than any mountains in the Alps; but where their summits are uncovered by snow, they are believed to be composed of secondary strata.

Many of the mountains in the extensive range of the Andés in South America also rise much higher than Mont Blanc; but granite has not been found there in a greater elevation than eleven thousand five hundred feet, an elevation exceeded by many of the granite mountains in Europe. The range of the Andes is the seat of active volcanic fires, which appear to have covered the primary mountains with an immense mass of matter, ejected by ancient and recent eruptions. In Mexico and New Spain also, the granite appears to be nearly covered by basalt, porphyry, and lava, ejected from the numerous volcanos which now exist, or have existed, in those countries.

To this accumulation of volcanic matter the mountains in South America owe their superior elevation.* Chimborasso and Cayambo are the highest mountains in the world,—the former rises twenty-one thousand four hundred and forty feet,—but their summits are vast cones composed of volcanic productions covered with snow. Chimborasso is one mile and one hundred and sixty yards higher than Mont Blanc. The general arrangement of the Andés consists, according to Humboldt, of granite, gneiss, mica, and clay slate, as in the Alps; but on these are frequently laid porphyry and basalt, "arranged in the form of regular and immense columns, which strike the eye of the traveller like the ruins of enormous castles lifted into the sky."

In the eastern parts of the United States, and in Canada, granite is seen near the surface uncovered by other rocks, and does not rise to any great elevation. The constant occurrence

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include pieces of different kinds of stone, which in fact are original parts of the rock, cannot be doubted; but in such cases there appears a gradual transition, from the substance of the rock, into the stone which appears imbedded.

* The author probably speaks of the height of these mountains above the country at their base and not of their elevation above the sea which is less than that stated above for the Himmaleh Mountains.—*Am. Ed.*

of granite at a lower level in America than in Europe, is a remarkable geological fact. In Europe the central part of the principal mountain ranges is granite; as in Scandinavia, the Alps, the Pyrenees, and the Carpathian mountains. In Asia, granite forms a considerable part of the Uralian and Altaic range of mountains, and it appears to compose the principal mountains that have been examined in Africa.

The parts of England and Wales where granite and granitic rocks occur, are Cornwall, Devonshire, North Wales, Anglesea, the Malvern Hills in Worcestershire, Charnwood Forest in Leicestershire, and in Cumberland and Westmoreland. The granite near Shap in Westmoreland is porphyritic, containing large crystals of red felspar. There are rolled masses of granite on the banks of Ulswater resembling the granite of some parts of Cornwall, and of the Wicklow Mountains in Ireland, but more highly crystalline than the latter. The felspar is in large white and reddish-white crystals. The mica is a blackish green, and on the outer parts decomposed. There is no similar rock in the vicinity known *in situ*. It has all the characters given by mineralogists to primary granite.[*] I am inclined to believe that the same formation of granite which just makes its appearance on the western side of South Britain is continued under the Irish Channel; or if broken there, it rises again in the Isle of Man, and in the counties of Dublin and Wicklow in Ireland. Blocks of granite are found in the beds of some of the rivers in the northwest part of Yorkshire, and in clay-pits in Lancashire and Cheshire, at a great distance from any granite mountains. Most of the granitic rocks on Charnwood Forest are of that kind denominated sienite.[†]

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[*] Since the publication of the former editions of this work, granite of a similar kind has been discovered forming the base of Skiddaw and other mountains in Cumberland.

[†] According to Brongniart, granite, sienite, and porphyry, are frequently observed graduating into each other in some parts of France; and he forms this conclusion: "En étudiant les granites d'un grand nombre de pays pour tacher de distinguer clairement les anciens granites des nouveaux, on trouve presque peu de pays granitiques qu'on puisse rapporter avec certitude à cette ancienne et primitive formation des granites."—*Journal des Mines*, *Mars*, 1811

Granite sometimes forms veins shooting up into the superincumbent rocks. This is a fact of some geological importance, as it seems to indicate, either that the granite has been in a state of fusion, the heat of which has softened and rent the upper rocks, and forced up the granite in a melted state into these fissures; or else that the granite and the rocks resting immediately upon it, were both in a fluid state at the same time, and are cotemporaneous. A remarkable instance of granitic veins in argillaceous schistus at Mouschole in Cornwall, is described in Dr. Thomson's Annals of Philosophy, May 1814. "The schistus is of a grayish colour, rather hard, but breaks in large fragments in the direction of the strata. The granite is of a fine grain, and the felspar is of a light flesh colour, and contains but a small portion of mica. At the junction numerous veins of granite may be traced from the rock of granite into the schist. Some of these veins may be observed upwards of fifty yards, till they are lost in the sea; and in point of size, vary from a foot and a half to less than an inch. It may deserve notice, that, as the felspar is of a flesh colour, it is impossible for any observer to consider them as quartz veins: one of these large veins is dislocated, and heaved several feet by a cross course. Quartz and fragments of schistus having the appearance of veins are found in the granite veins. At one place there is a very curious and satisfactory phenomenon. One of these veins of granite, after proceeding vertically some distance, suddenly forms an angle and continues in a direction nearly horizontal for several feet, with schistus both above and below it. This appearance most completely destroys one of the theories suggested for the explanation of similar veins at St. Michael's Mount, viz. that a ridge of projecting granite had been left, and schistus deposited afterwards on its sides."

In 1816, I visited the place, which is close by the sea side, at low water, and observed some appearances which I believe have not hitherto been noticed. The junction of the granite rock and the schist may be distinctly seen; they form together a sloping beach uncovered by any fragments; the line of junction is waving from the coast into the sea, as represented Plate 2. fig. 3.

It is truly worthy of notice, that the veins of granite may be distinctly seen penetrating both the schist and the granite; for the granite in the veins is finer grained than the granite rock, and may as easily be distinguished from it in the granite, as in the schist. The granite rock itself is smaller grained near the line of junction of the two rocks, than it is a little distance from it, where it contains large white crystals of felspar in a smaller grained reddish granite. What is further remarkable, the largest granite vein in passing into the schist, cuts through a vein of quartz thicker than itself; and a few yards nearer the sea, a small quartz vein cuts through the same granite vein: see Plate 2. fig. 3. What is called the schist or killas in Cornwall, in the places where I have observed it in immediate junction with granite, is highly indurated and of a dark colour, and appears to have been changed by the junction: it has no appearance of slate :—indeed the change in the size of the grain of granite, as the latter approaches the killas at Mouschole, would indicate that the two rocks were passing into each other. Perhaps the best designation of the killas rock on this situation is that of a minutely grained and highly indurated gneiss, that had lost its schistose character.

Granite veins of large size traverse granite rocks in the vicinity of Aberdeen: in these veins both the felspar and mica occur in crystalline plates and laminæ of considerable magnitude, accompanied with tourmaline. At Glentil in Scotland, a singular intermixture of granite in veins and amorphous masses occurs with slate and limestone, and has been described by Dr. MacCulloch in the Geological Transactions, vol. i. page 145. It seems impossible to conceive how masses of granite could be intermixed with, or imbedded in limestone, without admitting that the two substances have been both in a fluid or semi-fluid state at the same time, by whatever cause we may suppose this fluidity to have been effected. Such instances may make us feel less surprised at meeting with entire beds of granite in other rocks.

Some geologists describe the granite under gneiss and the granite over gneiss as different formations; but as gneiss is itself a schistose granite, it would be more correct to state, that the massive and schistose granite sometimes occur alternating with each other. When the mica becomes abundant, the granite passes to the state of gneiss; when the felspar and quartz predominate, it becomes again massive or common granite.

What has been said respecting the alternation of gneiss and granite, will apply to the alternation of granite and mica slate. In the latter, the felspar is wanting; but if it reappear, it becomes either granite or gneiss. Mica-slate also passes by such insensible gradations into slate, that the occasional occurrence of granite in some ancient slate-rocks may admit of a similar explanation. We shall thus sweep away the secondary granites, which have so much bewildered the systems of many Geologists: indeed nothing can appear more puerile and trifling, than the labour of making distinctions, where Nature has made none. Of this we have an instance in the distinctive characters which have been given of primary and secondary granite.

Primary Granite.	Secondary Granite.
1. Sometimes red.	1. Felspar commonly a deep red.
2. Contains garnets.	2. Contains garnets.
3. Is sometimes porphyritic.	3. Not porphyritic; but according to Professor Jamieson is sometimes porphyritic.

Again, M. D'Aubuisson tells us, that the colour of primary granite is almost always white.

What has been advanced may be sufficient to prove that the attempts to distinguish primary from secondary granite by their mineral characters, are worse than useless; as they waste the time of the learner, and tend to disgust him with a science already too heavily burdened with unmeaning terms and frivolous distinctions.

There is a particular form of granite, in which the constituent parts are so minute and so intimately mixed, that it appears very minutely granular or even compact: to this variety the French Geologists have given the name of *Eurite;* it has generally been described by English Geologists as *Compact felspar*, into which it passes by insensible gradations. This rock frequently contains large imbedded crystals of felspar, and forms what has been denominated felspar-porphyry. In Cornwall it occurs in beds in common granite; but instead of being regarded as a different rock, it may be more properly classed by the Geologist with granite, being only a variety in which felspar greatly predominates. This rock occurs also in an unconformable position, and is generally described as porphyry, and appears to form a connecting link between common granite and the compact varieties of volcanic porphyry, with a base of felspar call by the French *Trachyte.*

Sienitic granite, in which the mica is partly or entirely replaced by hornblende, in some situations occurs with common granite in the same bed, and therefore must be regarded as a variety of granite. Instances of this change from granite to sienite in the same rock, I have frequently observed in the granite of Charnwood Forest. The same change may also be noticed in the granite of the Malvern Hills. That able and accurate observer Dr. MacCulloch maintains the identity of granite and sienite, from their frequent passage into each other in the same rocks in Scotland. When the hornblende becomes abundant and is closely intermixed with felspar, it forms a dark finely granular rock, which has been denominated trap or greenstone: it nearly resembles basalt. In the Charnwood Forest hills, and at Shap in Westmoreland, well defined granite may be seen passing into a dark coloured trap-rock nearly compact. I have even broken off hand specimens in which one part was granite and the other trap, and the passage from one to the other might be distinctly observed.

The crystallized earthy minerals which occur most frequently in granite, are schorl or tourmaline, and pinite, a mineral nearly allied to mica,—the emerald, corindon, axinite, and topaz, are also found occasionally in granite. Sometimes the tourmaline is so abundantly disseminated, as to form a constituent part of the rock. Pinite occurs in considerable quantities in the earthy decomposing granites of Auvergne.

Common granite, or massive granite, contains few beds of any other rock, nor is it rich in metallic ores. Tin ore, however, occurs chiefly in granite, either in veins accompanying quartz, or disseminated through the rock at a distance from the veins. Ores of other metals, as copper, iron, wolfram, bismuth, and silver, are also occasionally found in granite.

Granite supplies durable materials for architecture; but it varies much in hardness, and care is required in its selection. I was told when in Cornwall, that granite got from a considerable depth in the quarry is so soft when it is first raised, that it can be easily sawed into blocks, but it soon acquires great hardness by exposure to the air. In the mountains of Auvergne, the granite is extremely soft, and the felspar appears earthy; this is probably the original state of the stone. I believe it is the soft earthy granite from this district which supplies the Kaolin used in the Porcelain manufacture at Sevres. Mons. Brongniart, who obligingly accompanied me through the works, showed me a specimen of their best Kaolin: it contained crystals of pinite. I had recently arrived from Auvergne, and I thought I recognised its locality.

Though granite may be regarded as the lowest known rock formation, yet it is certain, that in many countries the seat of volcanic fire is placed below granite. In Auvergne and a large part of central France, the foundation rock is granite; but it has been pierced through by numerous ancient volcanos, which have poured currents of lava over its surface, and covered other parts with loose scoriæ and black volcanic sand. Some of the currents of lava appear as fresh as the recent currents from Etna or Vesuvius. In other parts of Auvergne the granite appears to have been acted upon by subterranean fire *in situ;* and in some mountains, as in the Puy de Chopine near Riom, granite and volcanic rocks are intermixed, one part being true granite and the other volcanic porphyry, (trachyte.)*

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* See "Travels in the Tarentaise and Auvergne," vol. ii, p. 367.

The volcanos have long been dormant, and the only remaining proofs of the existence of subterranean fires under that district are the hot springs that rise in the vicinity of the ancient volcanos. According to Humboldt, in the Canary Islands, as well as in the Andés of Quito, in Greece, and various parts of the world, subterranean fires have pierced through the primary rocks; and he adduces the great number of warm springs which he has seen issuing from Granite, Gneiss and Mica-slate, as a proof of the truth of this opinion. Indeed, in the Andés numerous volcanos are in present activity, from Cape Horn to Mexico, and it is probable that those mountains owe their elevation to subterranean fire; for we have a recent instance of the mighty power of this agent to upheave the crust of the globe. During the earthquake in Chili in November 1822, the whole line of coast running north and south from Valparaiso, to the distance of one hundred miles, was raised above its former level; and the bottom of the sea was laid dry, and shells were discovered sticking to the rocks, some of which were not before known in those seas. It is stated by an observer, that the whole country, from the coast to the feet of the Andés and even far out to sea, was permanently raised by the earthquake; the greatest rise was about two miles from the shore. The granite which forms the foundation rock was rent in parallel fissures. The earthquake is estimated to have extended over an area of one hundred thousand miles. The average rise of the land upon the coast was from two to five feet, at a distance of a mile from the shore inland the elevation was seven feet.

During my residence in Savoy and Switzerland in the year 1820, -21, and -22, I was desirous to ascertain whether there were any vestiges of the action of subterranean fires in the Alps. In the part of the great southern chain, extending from near the source of the Rhone to the Little St. Bernard, there do not occur in the numerous situations which I examined, or from which I have seen specimens, any minerals of a volcanic character, with the doubtful exception of some rocks in the valley of Saas and in the Valorsine.

Though I could observe no indications of volcanic fire in the rocks themselves, I was greatly surprised with a circumstance that, as far as I know, had escaped the attention of geologists. Along the whole line of Alps before mentioned, which extends for one hundred and twenty miles, numerous hot springs are gushing out at the feet of the primary mountains near the junction of the lowest secondary limestone, with schistose rocks passing into mica and talcous slate. It was known that a few thermal waters existed in the Valois and in Savoy; but they were regarded as isolated phenomena, and their geological position had not been attended to. Since Saussure visited the Alps, thermal waters have been discovered in various situations; and since I left Savoy, another considerable warm spring has been opened in the vicinity of the village of Chamouni near the foot of a glacier.

There is also further reason to believe that thermal waters would be found in all the deep valleys of the Alps near the junction of the primary and secondary rocks, were they not covered by *eboulements* under heaps of loose stones, as was the case with the warm baths in the valley of Bagnes in the Bas Valois; or were not the temperature of the warm springs reduced by admixture with torrents from the glaciers.

In vol. i. chap. 8. of my "Travels in Savoy," I have described the geological position of nine of the principal known thermal waters of the Alps; their temperature varies from 94° to 126° Fahrenheit. The quantity of water which issues from these springs is very considerable, and the thawing of the bottom of the glaciers during intense frost, may I believe be attributed to the action of thermal waters. On the Italian side of the same range of Alps, particularly at St. Didider, near the steep southern escarpment of Mont Blanc, there are several thermal waters; and further west than the hot springs at Aix in Savoy, other hot springs have been recently discovered near Grenoble. It thus seems probable that there still exists under this range of the Alps one common source of heat, to the agency of which in remote ages, the mountains originally owed their elevation; for we can scarcely doubt that the hot springs in the Alps, like those in Auvergne, in Italy, or Iceland, derive their great temperature from subterranean fire. This inference is farther supported by the well authenticated fact, that the districts in which the hot springs are situated, have been subject to great and frequent convulsions. In the year 1755, the ground in the vicinity of the hot springs of Leuk and Naters, in the Upper Valois, was agitated with earthquakes every day from the 1st of November to the 27th of February. Churches were thrown down, the springs were dried up, and the waters of the Rhone were observed to boil in several places. The mountain above the warm spring at Naters is said to have opened and discharged a quantity of hot water.

The hot springs at the feet of the Pyrenees may derive their temperature from the same source as those on the Pennine Alps; the country that separates the Alps and the Pyrenees is in many parts volcanic.

What has been here advanced, may be sufficient to show the high probability, that the elevation of the vertical beds in the Alps has been effected by subterranean fire,—an agent which we have direct proof has in our own times elevated considerable portions of the crust of the globe; and it were contrary to the rules of sound philosophy to seek for other causes, than those which are now existing, when such causes are adequate to the production of all the phœnomena we observe.

CHAPTER VI.

ON GNEISS, MICA-SLATE, AND THE ROCKS WHICH ARE FREQUENTLY ASSOCIATED WITH THEM.

On the Passage of Granite into Gneiss.—Gneiss and *Granite veiné*.—Mica-Slate.—Crystalline or Primary Limestone.—Formation of Lime by Animal Secretion.—Origin of Calcareous Rocks.—Serpentine.—Euphotide or Saussurite.—Hornblende Rocks.—Compact Felspar.—Eurite, or White Stone.—Primary Porphyry a Mode of Granite.—Recurrence of the same Rocks in the different Rock formations.

The principal primary rocks enumerated with granite in the preceding chapter were Gneiss and Mica-slate. With these, certain rocks are frequently associated, and are therefore regarded as cotemporaneous; for where one rock occurs imbedded in another, it is evident that the inclosed rock must be as ancient as the rock which enfolds it; and therefore if one be primary, the other must also be primary, unless the imbedded rock be volcanic. Gneiss received its name from the German miners: according to Mr. Jameson, the decomposed stone on the sides of some metallic veins was first so called; but Werner designated by this term a schistose or slaty granite, abounding in mica. Granite frequently passes into gneiss by an almost imperceptible gradation: where the quantity of felspar decreases and the crystals or grains become smaller, if the mica increases in quantity, and is arranged in layers, the rock loses the massive structure, and becomes schistose; we have then a true gneiss. By the reverse of this process, if the quantity of felspar increases, and the mica diminishes, the rock loses the schistose structure and becomes massive; and we have granite again. Some geologists call this secondary granite, but the upper and lower granite, and the gneiss are in this instance but different modes of the same rock.

The granite of the Alps which Saussure calls *granite veiné*, is properly an incipient state of gneiss; the mica is arranged in parallel layers, varying in distance from each other; when they approach very near, they form what in hand specimens is called true gneiss. When the parallel layers of mica are at some distance from each other, they give a striped appearance to the rock. Laminæ of quartz of considerable thickness sometimes separate the felspar from the mica, and occasionally masses of quartz are imbedded in gneiss. When the mica becomes very abundant, and the other constituent parts are small in size and quantity, gneiss passes into mica-slate;—gneiss has often a waved form. This rock has been represented as stratified, I conceive, by a mistake in confounding the stratified with the slaty structure: the latter is occasioned by the quantity of mica and sometimes of talc which it contains, and is the effect of crystallization.*

Beds of crystalline limestone, and of hornblende rock, occur in gneiss. It contains most of the metallic ores, both in veins and beds. Crystals of garnet are frequently interspersed in gneiss, but are more common in micaceous schist, which is nearly allied to this rock.

The declivities of granite mountains are covered by rocks of gneiss in many parts of the world. Gneiss constitutes the principal rock-formation in a considerable part of Sweden. It occurs in Scotland and Ireland, but is scarcely known in any part of England or Wales. Very well characterized gneiss occurs in the vicinity of Aberdeen. An imperfectly formed gneiss is found on the Malvern Hills. I have also seen gneiss brought from the lower part of Skiddaw in Cumberland. Mountains of gneiss are not so steep and broken as those of granite, and the summits are generally rounded.

Mica-slate or *Micaceous schistus* is frequently incumbent on gneiss or granite, and covered by common slate; it passes by gradation into both these rocks,—the coarser grained resembling gneiss, and the finer kind, by insensible transition, becoming clay-slate.

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* The partings or divisions in rocks, which may properly be denominated rents, are distinct from those which are the effect of crystallization, and may be distinguished by their irregularity, roughness, and the indeterminate manner in which they intersect the stone.

Mica-slate is composed essentially of mica and quartz intimately combined; the felspar, which is a principal constituent part of granite and gneiss, occurs only occasionally in irregular masses in this rock. The colour of mica-slate is generally a light gray, inclining sometimes to green or yellow; the finer kinds have a pearly lustre;—in the coarser kind the laminæ of mica are more distinct and splendent. Crystals of garnet are frequently disseminated in mica slate; it contains occasionally crystals of other minerals. It has a slaty structure, and is often waved and contorted, and divided by thin laminæ of quartz. It sometimes contains beds and laminæ of crystalline limestone, or is intermixed with serpentine. Mica-slate also frequently contains beds and veins of metallic ores. The gradation of mica-slate into gneiss and clay-slate, and the transition from granite to mica-slate, may be distinctly seen in some of the rocks near Bray, in the county of Wicklow in Ireland. I have observed that the beds of mica-slate adjoining the granite are traversed by numerous and large seams of quartz running parallel with the slaty structure of the rock, and increasing in size as they approach the granite. The quartz has a greasy aspect, and is evidently of cotemporaneous formation with the mica-slate and granite.

Mica-slate has a near affinity to clay-slate; and as I have arranged the latter with rocks of the second class, it may perhaps be doubted whether mica-slate should not also have been transferred to the same class. No well characterized rocks of mica-slate of any extent occur in England. I have observed a micaceous rock, which may be considered as an imperfect kind of mica-slate near the granitic rocks of Mount Soar Hill; but it was covered by wood, which concealed its junction with other rocks. On the western side of Anglesea, near Holyhead, there are numerous rocks of an intermediate kind between mica-slate and talcose-slate. The laminæ are separated by very thin seams of quartz; and I have observed some of them bent and contorted in various directions, as is not unfrequently the case with mica-slate in other districts

The mica-slate on the opposite coast of Ireland, near Bray, I am inclined to consider as of the same formation with that in Anglesea. Probably this rock stretches under the Irish Channel, of which it may form the bed in that parallel of latitude. The structure of both rocks is the same, presenting the same divisions by thin laminæ of quartz; but the mica of Anglesea is more combined with talc. Mica-slate abounds in the Highlands of Scotland, and in many alpine districts in Europe, particularly in the Pennine Alps.

Gneiss and mica-slate are nearly allied to each other and to granite. Circumstances attending the formation of granite appear to have produced a different arrangement of the component ingredients. This is the more probable, as both gneiss and mica-slate sometimes graduate into granite, and have at other times a porphyritic structure. In some situations the causes which change granite into gneiss or mica-slate have not operated, and we find neither of these substances separating granite from the rocks of the next class.

Mica is nearly allied to talc, and mica-slate frequently passes by insensible gradations into talc-slate or talcy mica-slate: a considerable part of the granite of Mont Blanc is of this kind.

Gneiss and mica-slate being nearly similar in their constituent parts and geological position,—most of the metallic ores and minerals that occur in one rock, occur also in the other. Crystalline limestone, hornblende, talc, and serpentine, more frequently form beds in mica-slate than in gneiss. The waved structure is very common in mica-slate, and the beds are often most singularly bent and contorted.

Crystalline or primary limestone, of which statuary marble is a variety, occurs principally forming beds in primary mountains; beds of this mineral occur rarely in granite, more frequently in gneiss, but are most common in mica-slate, with which rock it is often much intermixed, and often alternates with it. It is observed that the primary limestone in granite and gneiss, is coarser grained than that in mica-slate or common slate. Primary limestone is often much intermixed with serpentine. When beds of primary limestone occur of considerable thickness, they sometimes contain veins of metallic ores.

Crystalline or primary limestone when pure is composed of calcareous earth, which scarcely exists as a component part of granite, gneiss, or mica-slate. No organic remains are found in the crystalline limestone in primary mountains; the structure is granular; the white variety known as statuary marble resembles fine loaf-sugar, and is imperfectly translucent; hence it has been called by the French *chaux carbonatée saccaroide.* The colour of primary limestone is sometimes yellowish, greenish, or inclining to red. From a mixture of mica it has often a slaty fracture and divides in plates, from which circumstance it has been described as stratified,—a term not applicable to rocks that are granular and purely crystalline. It may be further deserving notice, that primary limestone or statuary marble frequently contains a considerable quantity of siliceous earth, to which it owes its hardness and durability. White crystalline statuary marble occurs in the Isle of Sky, one of the Hebrides, and many rocks of crystalline marble intermixed with mica-slate and serpentine, are found in different parts of Scotland. Neither in England nor Wales have any rocks of limestone been found which possess the crystalline translucent qualities of statuary marble, though very beautiful marbles occur which will receive a high polish; these belong to the limestone which will be described in the following chapter.

White marble is procured from Italy, Switzerland, and the Grecian Archipelago. Primary limestone exists in beds of greater or less magnitude, which are sometimes so thick as to form entire mountains. It was once supposed that all calcareous rocks and strata are composed of the shells of marine animals, and it cannot be doubted that many of them are entirely formed of these organic remains: but in the beds of primary limestone, and even in some of the secondary limestones, no vestiges of such remains occur. It may be said that the process by which primary limestone was crystallized, destroyed all traces of organization; and though it would be impossible to disprove this, yet there is no reason to believe that lime may not exist as an elementary earth, like silex or alumine, independent of the operations of animal life. It does so exist as a component part of many minerals, and it may have existed in sufficient quantity, to form the mountains of primary limestone.

It is however a curious but undoubted fact, that no inconsiderable portion of the earth's surface has been formed by organic secretion, and the process is still going on rapidly and extensively in the Southern Ocean. According to the observations of voyagers, islands and reefs of coral rocks are raised from vast depths in the course of a few years. Thus, millions of minute marine polypi are preparing future abodes for other classes of animals of larger size, and living in another element. From whence do these innumerable zoophytes and moluscous animals procure the lime which, mixed with a small portion of animal matter, forms the solid covering by which they are protected? Have they the power of separating it from other substances, or the still more extraordinary faculty of producing it from simple elements? The latter I consider as more probable; for the polypi which accumulate rocks of coral from unfathomable depths have no power of locomotion; their growth is rapid, and the quantity of calcareous matter they produce in a short space of time, can scarcely be supposed to exist in the waters of the ocean to which they have access, as sea-water contains but a minute portion of lime.

It is now ascertained that lime and the other earths are compounds of oxygen united with metallic bases; and the brilliant discoveries of Sir H. Davy respecting the metallic nature of ammonia, would lead to the conclusion that the metallic bases of all the alkalies and alkaline earths, which have many properties in common, may like ammonia, be compounds of hydrogen and azote, but differently combined. Now it is well known that hydrogen and azote, which exist as elementary constituent parts of almost all animal substances, may be derived from water and the atmosphere; and should the compound nature of the metallic bases of the earths be ascertained, the formation of lime by animal secretion, will admit of an easy explanation.

Serpentine derives its name from its variegated colours and spots supposed to resemble the serpent's skin: its chemical composition has been before described. The colours are most generally various shades of light and dark green which are intermixt in spots and clouds; some varieties are red. When fresh broken it has some degree of lustre, and a slightly unctuous feel; when pounded, the powder feels soapy. It is harder than limestone, but yields to the point of a knife, and will receive a very high polish. When serpentine is found intermixt with patches of crystalline white marble, it constitutes a stone denominated verde-antique, which is highly valued for ornamental sculpture. Some varieties of serpentine are translucent, in others there is an appearance of crystallization, forming a mineral called diallage or schiller-spar. The minerals associated with serpentine are generally those allied to talc. Compound rocks in which talc and hornblende are predominating ingredients, pass into serpentine. Magnesia enters largely into the composition of these rocks. A late analysis of one kind of serpentine, gave 48 per cent of this earth. Serpentine occurs chiefly in gneiss and mica-slate, in beds which are frequently so thick as to compose mountain masses of considerable height. Serpentine sometimes becomes magnetic, from an intimate intermixture with minute particles of magnetic iron stone. Many of the alpine districts in Europe contain rocks and beds of serpentine; but according to Patrin, there is no serpentine in Northern Asia, nor was it seen by Humboldt in the Andes; but it is not uncommon in the United States of North America. In the Alps it is observed that the rocks of serpentine lie principally on that side which faces Italy and the coast of Genoa. There is a soft kind of serpentine, sufficiently tenacious to be turned in a lathe into vessels of any shape, which resist the action of fire: hence they are used for culinary and other purposes in some parts of Switzerland, in Lombardy, and even in Higher Egypt. The use of this stone is of great antiquity being distinctly mentioned by Pliny; it is called *lapis ollaris*, or pot-stone.

In Cornwall serpentine occurs with a micaceous rock lying over granite, and forms part of the promontory called the Lizard

Point, and it occurs again on the eastern side of the same county at Liskeard. It is not met with in any other part of England that I know of; but I have observed rocks approaching the nature of serpentine in Charnwood Forest, and in the county of Radnor in Wales.

Beautiful varieties of red and green serpentine occur in the Isle of Anglesea, about six miles from the Paris copper-mine. It is found in beds of great thickness associated with the common slate-rocks of the district, which approach in their nature to talcous slate: asbestus lies in considerable quantities in the partings between the beds of serpentine.

Some of the specimens of this serpentine have the characters of the precious or noble serpentine; the colours are principally dark green, intermixt with spots and clouds of lighter green and shining laminæ of schiller-spar or crystallized serpentine. The fracture is conchoidal, and it is translucent at the edges. It resists the point of a copper or brass tool, and breaks with great difficulty. Some varieties contain crystalline limestone, but in smaller patches than in the Italian verde-antique; occasional stripes and spots of steatite, asbest, and quartz, occur in it. The red is sometimes intermixed with a great variety of other rich colours in the same stone, as black, white, greenish white, and dark green. It may be considered as a valuable stone for purposes of ornamental architecture, for in beauty and durability it is not exceeded by the costly marbles of Greece or Italy.

By a mixture of serpentine with talc or steatite, serpentine becomes soft and sectile, and forms the mineral called potstone before mentioned. A different combination of crystallized serpentine (*diallage*) with jade or felspar, forms one of the hardest and heaviest of known rocks. It was first noticed by Saussure in rounded pieces and loose blocks, scattered over several parts of the valley near the Lake of Geneva; to this mineral the name of Saussurite has been given. It is much harder than quartz, and its specific gravity is 3·35: the colour generally inclines to green. For a considerable time it was unknown where this rock occurred *in situ*; it has since been discovered in immense beds, associated with serpentine, in the valley of Sass in the Haut Valois. Beds of the same rock occur on the southern side of the Alps and in the Appennines. A very interesting description of the Saussurite and serpentine of the Appennines has been published by M. Brongniart, entitled *Sur le Gisement ou Position relative des Ophiolites, Euphotides et Jaspes, dans quelques Parties des Appenins.** In these mountains, the serpentine rests upon saussurite, the saussurite, on strata of jasper, and the latter on transition or secondary limestone. This position is remarkable, for geologists had generally supposed that all serpentines were more ancient than the secondary rocks.

Hornblende rock and *Hornblende slate.*—This mineral has been described Chap. III. When it forms the principal parts of rocks, the colour is commonly a greenish black. Massive hornblende in rocks is generally coarsely granular and lamellar; in hornblende slate it is frequently radiated or fibrous, and when the fibres are very minute it has a velvet-like lustre. Hornblende slate occurs in beds in granite, gneiss, and mica-slate, and occasionally in common slate it appears to pass by gradation into serpentine; the change is effected by an increase of magnesia, which forms one of the constituent parts of hornblende.

Hornblende in large lamellar grains, intermixed with felspar, forms sienite, which it was remarked in the last chapter is not unfrequently associated with granite: the passage of one rock into the other by the increase or decrease of felspar, may frequently be observed in the same mountain. When hornblende and felspar are more intimately blended, they form the rock called by the Germans *Green stone*, by the French *Diabase;* and with other rocks of similar composition are frequently described as trap-rocks, and by the French as *roches amphiboliques:* these will be more properly noticed in the subsequent chapters. When the hornblende and felspar are so closely and minutely intermixed that the rock appears homogeneous, the trap has all the external character of a rock (hereafter to be more fully described) called Basalt.* In examining the geological specimens of Saussure in the museum at Geneva, I observed that the rocks which he so frequently mentions under the name of *Cornéene*, are mixtures of hornblende and felspar, in which the former mineral predominates.

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* It is to be regretted that so excellent an observer and mineralogist as M. Brongniart, who is so justly eminent for his scientific labours, should have thought it necessary to burden Geology with two additional new names. Serpentine he has denominated *ophiolite*, and saussurite *euphotide.*

Hornblende intermixed with felspar, forming sienite and greenstone, occurs at the Malvern Hills in Worcestershire, at the Charnwood Forest hills in Leicestershire, and in Cornwall, Cumberland, and North and South Wales. Very little well characterized hornblende slate is found in any part of England, but it occurs abundantly in the alpine parts of Scotland, and in most of the principal mountain ranges in Europe. The various intermixtures of hornblende and felspar, to which the name of trap-rocks is frequently given, may more properly be classed with transition rocks.

Porphyry derives its name from a Greek word denoting *purple*; the rock to which it was at first applied had a purple colour. In the modern acceptation of the term, any rock which is compact or finely granular, and contains distinct imbedded crystals, is called Porphyry, whatever be its colour. The base or paste of most porphyritic rocks is felspar; and the imbedded crystals are also felspar, though there may be also small grains or crystals of other minerals. It has been stated in the preceding chapter, that granite, by becoming finer grained, frequently passes to the state of porphyry. The *eurite* of the French geologists, and the *weiss-stein* or *white stone* of Werner, is a granite in which the felspar is the principal constituent part, and is either finely granular or nearly compact. To this variety English geologists give the name of compact felspar: the white elvan of the Cornish miners is a porphyritic eurite.

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* The rock to which the French give the name of Diabase, the compact trap of Werner, resembles basalt (which the French call Dolerite) so closely both in composition and physical characters, that the division into two species seems principally made to serve the purpose of theory. Diabase is composed of felspar and hornblende, and dolerite of felspar and augite intimately combined. But as hornblende and augite do not differ more in chemical composition, than one species of hornblende differs from another, and as these two minerals are to be distinguished only by their crystallization; when they occur uncrystallized, may they not be regarded as identical? It is true, augite occurs abundantly in rocks of undoubted igneous origin and in the lavas of recent volcanos; hornblende occurs also in basaltic lavas, but more frequently in rocks of which the igneous origin is not generally admitted; yet it may be fairly doubted, whether the distinction between compact diabase, and compact dolerite, has not been made in order to form gratuitous conclusions respecting the different origin of rocks, which are in chemical composition and external character essentially the same.

Geologists have described four formations of porphyry, but it is generally agreed that there is much uncertainty with respect to the situation of these formations. The porphyry which occurs imbedded in granite, or which appears to be formed by a change of structure in that rock, may properly be classed with primary rocks: it is not considered to be an extensive formation; the white elvan of Cornwall, and probably the porphyry associated with mica-slate in Argyleshire, belong to this formation. Porphyry also occurs in enormous masses covering both primary and transition rocks unconformably; but this porphyry belongs more properly to transition rocks, and will be described with them in the following chapters. Porphyry is sometimes a volcanic rock, and appears to form the connecting gradation between granitic rocks, and those of igneous origin.

Before taking leave of the rocks classed as Primary, it may be proper to notice that some of the rocks associated with granite, gneiss, and mica-slate, occur also in the transition class, and even in the lower secondary strata. The same causes by which they were formed among primary rocks, have also operated at a later period: indeed one of the well known rocks, limestone, has been deposited or formed in all the different classes of rocks except the volcanic, and must therefore receive its name from the class with which it is associated; as primary limestone, transition limestone, &c. In some instances the mineral characters, or the fossils, serve to distinguish rocks of the same kind, that occur in the different classes or formations: thus the rocks associated with primary rocks are generally harder and more crystalline than the same species of rock which occurs in the secondary class; but this is not invariably the case.

CHAPTER VII.

ON TRANSITION OR INTERMEDIATE ROCKS.

Character and Classification of Transition Rocks.—Slate; the Clay-slate of Werner.—Roof Slate, its Cleavage not the Effect of Stratification, but of Crystallization.—Talcous Slate.—Whet-stone Slate.—Flinty Slate.—Greywacke and Greywacke Slate, its Passage into Red Sandstone and Gritstone.—Errors of English and Foreign Geologists respecting the Old Red Sandstone and Mountain Limestone.—Old Red Sandstone.—Transition Limestone.—Transition Limestone of Devonshire, and Dudley in Staffordshire.—Upper Transition or Mountain Limestone.—Its Connection with Coal Strata.—Observations on the Fossils in Transition Rocks.

Transition or intermediate rocks cover rocks of the primary class, and are distinguished as the lowest rocks in which the fossil remains of animals or vegetables are found; they may be regarded as the most ancient records of our globe, imprinted with the natural history of its earliest inhabitants.

Transition rocks are the principal repositories of metallic ores, which occur (both in veins and beds) more abundantly in many of the rocks of this class, than in primary rocks. Metallic veins very rarely occur in the secondary strata.

Geologists have often been perplexed in their attempts to draw a well marked line of distinction between primary and transition rocks: the difficulty has arisen chiefly from their arranging slate with the primary class; and hence the disciples of Werner have been obliged to introduce the theoretical terms of newer and older primary slate, and newer and older transition slate, &c. If the occurrence of organic remains in rocks be the characteristic distinction between the primary and transition class, slate must certainly be classed with the latter; for it is among slate rocks that the fossilized remains of animals and vegetables first appear, in every country, that has yet been examined. One of the disciples of Werner, M. D'Aubuisson, admits that there is no where any extensive formation of primary slate. M. Bonnard another disciple of the same school, in his *Apperçu Geognostique des*

Terrains, after enumerating various primary slate rocks, candidly acknowledges that it is doubtful whether primary slate can any where be found. It is true, that mica-slate passes by almost imperceptible gradations into common slate; but here as in other instances, we only find that Nature is not limited by the artificial arrangements of the geologist: yet so long as it may be proper to class rocks containing organic remains, with transition rocks, we must place slate among them. Nor can this be invalidated by the fact, that in some slate rocks no vestiges of animal or vegetable remains occur; for among the secondary strata, abounding in such remains, we often meet with alternating beds, in which they are never found; but we do not on that account class them with primary rocks. In arranging transition rocks, I most decidedly place the English mountain limestones among them, as I have done in the former editions of this work. I know no circumstance in Geology that evinces more strongly the tenacity with which errors are cherished, when they have been some time entertained, than the determination of English geologists to separate mountain limestone from transition limestone, —in opposition to analogy, and to the universal opinion of geologists on the continent. This separation as a mere matter of classification, would be in itself of little importance; but it has tended more than any other circumstance to perplex both foreign and English geologists, in their attempts to assimilate the rock formations of England, with those on the continent of Europe.

When a general attention was first excited in this country to the study of Geology, access to the continent was extremly difficult, and we were left to explore as well as we could the geology of our own island, enlightened only by the dark-lantern of German Geognosy. Many characters were given of transition rocks, and flœtz or parallel rocks, founded on local observations in Germany, which did not apply to the rocks in other countries: it was found that the characters of our metalliferous limestone did not agree very well with either, and therefore English geologists have retained the name of mountain limestone, and the appellation of transition limestone was restricted to a lower bed, small in extent, and comparatively unimportant. When I first visited the continent, and examined the cabinets of some eminent geologists, I was particularly struck with finding the *analogues* of our principal beds of mountain limestone exhibited as types of true transition limestone. On my return to Paris the following year, I took specimens of our mountain limestone from Derbyshire, Westmoreland, Somersetshire, and Wales; and also of the lower limestones, from Shropshire and Devonshire, and presented them to Messrs. Brongniart and Brochant. The whole of the specimens they recognized as transition limestones, and selected the encrinal and dark madrepore mountain limestone, as the true types *par excellence—des Calcaires de Transition.*

The following arrangement of transition rocks, comprises the lowest rocks in which organic remains occur, and those which are metalliferous, or are associated with metalliferous rocks.

TRANSITION CLASS

(conformable.)

1. Slate, including flinty slate and other varieties.
2. Greywacke and greywacke slate, passing into old red sandstone.
3. Transition limestone. Mountain limestone.

Rock covering Transition Rocks (unconformably.)

4. Porphyry, passing into trap or greenstone.
5. Clink-stone passing into basalt.
6. Basalt.

Slate—of which roof-slate is a well known variety—is called by the Germans *Thon scheiffer* or *clay slate;* by ancient English geologists, argillaceous schistus; by the modern French, *Phyllade.* The term *slate* is perhaps the most proper that can be used to designate this rock; as the best variety of it, Roof-slate, is well known. Clay-slate is a name given from an erroneous opinion respecting its constituent parts; and the term is liable to create much confusion, as the softer kind of slate in the coal strata is called slate-clay. I shall therefore throughout the present volume substitute the term *slate* for clay-slate, and for slate-clay the more intelligible English term *shale*.

Slate rocks abound in most alpine districts, resting either on granite, gneiss, or mica-slate. That slate which lies nearest the primary rocks has a more shining lustre than the other, and partakes more of the crystalline quality of mica-slate. As this rock recedes from the primary, its texture is generally more earthy. Its colours are various shades of gray, inclining to blue, green, purple, and red. Some kinds of slate split into thin laminæ, which are well known as forming roof-slates. Slate rocks are commonly divided into beds of various degrees of thickness, which generally are much elevated, and from the natural divisions of the rock, they often form peaked and serrated mountains.

Slate has been described by former geologists as distinctly stratified, because it splits easily into thin laminæ, and the direction of the laminæ is asserted to be in the direction of the beds: but in opposition to the authority of many eminent geologists, I maintain that slate, unless it be of a soft or coarse kind approaching to shale or greywacke, invariably splits in a transverse direction to that of the beds, making with that direction an angle of about sixty degrees; it has frequently two distinct cleavages.

Few persons have perhaps examined more slate rocks, or consulted more workers in slate quarries than I have; and the fact respecting its cleavage is invariably what is here stated, except in very coarse greywacke slate, and soft slate or shale.

Slate rocks vary much in quality in the same mountain; those which contain a great quantity of siliceous earth pass into flinty slate. When magnesia enters largely into the composition of slate rocks, they are distinguished by their green colour, and pass into chlorite, or talcy slate. Whetstone slate, or hone, is a variety of talcy slate, containing particles of quartz; when these particles are extremely minute, and the slate has a uniform consistence and requisite degree of hardness, it forms hones of the best quality. Carbonaceous matter is first discovered in slate rocks, and increases in quantity, as they approach the secondary strata. Drawing-slate is stated to contain 11 per cent of carbon; where the carbon is very abundant, the slate has a dark colour, and is generally soft. Impressions of vegetables are found in some slate rocks that were formerly regarded as primary; the slate rocks in the vicinity of Mont Blanc, and Mont Cenis, contain impressions of ferns.

That fine variety of slate which is used for roof-slate, seldom forms entire mountains, but is generally imbedded in slate rocks of a coarser kind: the beds of roof-slate are sometimes of considerable thickness, and generally rise at an elevated angle. If geologists had not been induced, by an attachment to theory, pertinaciously to adhere to opinions once received, they could not have failed to recognise the effect of crystallization in the cleavage of slate, as evidently as in the laminar divisions of felspar.

Those varieties of roof-slate are preferred for the covering of buildings, which have the smoothest surface and split into the thinnest plates; they are, however, frequently made too thin to be durable, and too light to resist the force of the wind during storms.

Quarries of slate are worked extensively in Westmoreland, Yorkshire, Leicestershire, North Wales, Cornwall, and Devonshire. The foreign localities of slate are so numerous, it would be superfluous to name them.

Mountains of slate are seldom so precipitous as those of granite; they are covered with verdure on their declivities, as they contain less silex and a more equal admixture of the earths favourable to vegetation.

Flinty slate, as before observed, differs from common slate by containing a greater quantity of siliceous earth; and, as its name implies, it partakes of the nature of flint. Slate and flinty slate not only pass into each other, but frequently alternate. When the latter ceases to have the slaty structure, it becomes hornstone, or what the French denominate petro-silex. If it contain crystals of felspar, it becomes hornstone porphyry; all these varieties may be observed alternating with each other, in the same rocks in Charnwood Forest, and in North Wales and Cumberland.

Slate is regarded as one of the most metalliferous rocks: nearly all the principal metallic ores have been found in slate, either in veins or beds; but it is remarkable that flinty slate seldom contains any repositories of metallic matter. Lead and copper are the principal metals found in the slate rocks of England and Wales; they are not so rich in lead as the mountain limestone, but the lead ore in slate rocks contains a larger portion of silver.

Greywacke and *Greywacke Slate;* German *Grauwacké.*— This dissonant term, which we have borrowed from the German, the French geologists have exchanged for a name not more harmonious, though more expressive, *Traumate*, from the Greek *Thrausma* a fragment.

Greywacke in its most common form may be described as a coarse slate containing particles or fragments of other rocks or minerals varying in size from two or more inches, to the smallest grain that can be perceived by the eye. When the imbedded particles become extremely minute, greywacke passes into slate. When the particles and fragments are numerous, and the slate in which they are cemented can scarcely be perceived, greywacke becomes coarse sandstone or gritstone. When the fragments are larger and angular, greywacke might be described as a breccia with a paste of slate. When the fragments are rounded, it might not improperly be called an ancient puddingstone. When rocks of greywacke have a slaty structure, they form greywacke slate.

Greywacke has by some of the French geologists been described as a transition sandstone, with a cement either of siliceous earth, or of slate. This definition agrees with the gritstones associated with the upper transition or mountain limestone. Where the paste is hard and siliceous, as I have observed in the greywacke of Savoy that separates the primary from the secondary rocks, many of the siliceous particles may have been original concretions, formed at the same time as the paste; and where these concretions are all composed of quartz, we may infer that such has been their mode of formation. In other instances, the fragments are evidently the debris of more ancient rocks, that have been broken down by some great catastrophe, and mixed with more recent beds at the period when they were forming. This mode of formation implies, that a considerable period elapsed between the formation of the primary and secondary rocks. The fragments are always those of lower rocks, and never of the upper strata. In some situations immense beds of loose conglomerate, composed of large fragments and boulders of the lower rocks, separate the slate rocks from the calcareous formations: such conglomerates may be regarded as occupying the geological place of greywacke, and belonging to the greywacke formation.

The old red sandstone, about which so much has been written and so little understood, is a greywacke coloured red by the accidental admixture of oxide of iron. In Monmouthshire, the relations of red sandstone with greywacke, and the passage of one rock into the other, may be distinctly observed; the connection also with the lower gritstone, under the mountain limestone, may be plainly traced. Here then we have the mountain limestone with its alternating beds of grit, the red sandstone and the greywacke, evidently members of the same formation; and to make the connection more complete, the red sandstone contains beds of limestone, which form the link between the lower transition and the upper transition limestones. This limestone is imperfect, being intermixed with siliceous particles; it is of a greenish colour, and hence called Gooseberry limestone. The red sandstone also passes into clay stone, as well characterized as that of the Pentland hills.*

The old red sandstone possesses all the mineral characters of greywacke except the colour, which is a quality that can never be considered of importance, being derived chiefly from local or accidental causes. The old red sandstone also occupies the geological position of greywacke and greywacke slate, into which it passes merely by a change of colour. The principal reason why it has not been generally recognized as belonging to the greywacke formation is, that it has frequently been confounded with the red sandstone above the coal formation: they greatly resemble each other, and it is not yet clearly ascertained, whether the red sandstone in some parts of England be the old red sandstone or the new. Until English geologists shall renounce their prejudices, and place the old red sandstone and mountain limestone in the Transition Class, as greywacke, and transition limestone, every attempt will be vain to identify this part of the geology of England with that of the Continent: particularly as the Alpine limestone of foreign geologists, is a very different formation from the transition limestone, comprising the several formations of limestone above the coal strata, and new red sandstone, or what the French call *Grès bigarré.*

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* From the quantity of oxide of iron and of red marle in some beds of the old red sandstone, and from its passage into clay-stone, I am inclined to believe that the red sandstone of Monmouthshire has been formed partly by the decomposition of an ancient basaltic formation, which has become intermixed with greywacke.

Transition limestone.—This is one of the most important of the transition rocks: its mineral characters vary considerably, according to the nature of the rocks with which it is associated; it has generally a subcrystalline texture, and is more or less translucent on the edges. From the degree of hardness which it possesses, it will take a good polish: most of the coloured marbles are transition limestone. The prevailing colour is bluish grey, but it is sometimes red, brown, or black; the lower beds of this limestone are often beautifully variegated, veined, and spotted. It may be stated generally, that transition limestones are seldom so perfectly crystalline as primary limestones, and they have rarely the compact and earthy texture of secondary limestones.

Transition limestone occurs in beds alternating with slate, greywacke, greywacke slate, and coarse gritstone. Some of these beds are of considerable thickness, and form mountain masses. The lowest beds alternate with slate; they contain few organic remains. The variegated limestone of Devonshire is of this kind. Sometimes numerous thin strata of slate and transition limestone alternate, and are much bent and contorted. A very remarkable instance of this occurs at Drewsteignton near Moreton in Devonshire, where a series of thin strata of dark limestone, alternate with strata of indurated slate, and are bent and folded in various

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directions. Were we to take a number of alternating sheets of black and brown paper, and fold them nearly round a wine decanter, and then bend them back over the lower folds, we should have a not unapt representation of the singular contortions of the strata in this place, where they are exposed to view by extensive quarries cut in the rock.

The remarkable contortions of the beds of transition limestone and slate, imply the operation of a cause that could not only bend but soften the strata; and were we to admit that granite has once been in a state of fusion, and been protruded through the outer crust of the globe, the immediate contiguity of these bended strata to the granite of Dartmoor might indicate the agent by which the effects were produced. Near Dudley, in Staffordshire, we have another remarkable instance of the bending of beds of transition limestone; but this is in the vicinity of basaltic rocks, which are now admitted to be of igneous origin.

The limestone at Wren's Nest, near Dudley, consists of two beds, one ten, and the other fourteen yards thick, resting upon beds of soft and imperfect limestone and shale, called *wild measures*. The two beds of limestone are separated by similar strata of wild measures thirty-eight yards in thickness, and are raised up together in a position approaching to vertical, and are folded round the hill inclosing a space of about fifty acres, with a double wall of limestone rising above the country, like an oval tower widening at the lower part.

If two sheets of pasteboard were separated by a quire of writing paper, and laid flat, and a blunt metallic rod were thrust through the whole from beneath, it would force the lower sheet of pasteboard through the upper sheets, and represent the present position of the strata at Wren's Nest Hill. At Dudley Castle Hill, about a mile distant, the beds of limestone are bent, and dip on each side of the hill. (See a section of this Hill, Plate 3, fig. 4.)

The transition limestone of Dudley is not covered by any beds of the upper transition or mountain limestone, but by strata about seventy-six yards in total thickness, composed of imperfect limestone and sandstone, which separate it from the lowest coal measures. It is therefore to be particularly noticed, that the coal strata which in most of the coal districts in England rest upon the upper transition or mountain limestone, in this part of Staffordshire rest upon the lower transition limestone. The remarkable fossil the trilobite, called the Dudley fossil, occurs principally if not entirely in a stratum under the first limestone. There are shells in what are called the wild measures, but they are in a soft and decomposing state.

The lower transition limestone in England and Wales is not a very extensive formation: it skirts the granite of Dartmoor, and part of the Malvern Hills; it extends in a narrow belt from Wenlock in Shropshire, to Caermarthen in Wales, and is generally accompanied with soft greenish schistose strata, called provincially Dye Earth, which contain numerous impressions of shells. A few patches of this limestone occur in various parts of the slate districts in Wales and Cumberland. This part of the transition limestone series, is chiefly remarkable for its organic remains; it is rarely metalliferous.

The upper transition or mountain limestone is, as I have before stated, the limestone to which the French geologists gave, *par excellence*, the name of *Calcaire de transition*. It is by many English geologists considered as a distinct formation from the lower, or what they call the true transition limestone; and it is said to be "separated from it by the important formation of the old red sandstone:" but the latter is only a variety of greywacke, and is acknowledged even by those who make it a distinct formation, to graduate into greywacke, and possess all the general characters of that rock, except that it is colored red. It contains in some situations beds of imperfect limestone, which may be said to connect the lower transition and mountain limestones in one formation, together with the associated beds of greywacke, red sandstone, and gritstone.

Mountain limestone is one of the most important calcareous rocks in England and Wales, both from its extent, the thickness and number of its beds, the quantity and variety of its organic remains, and its richness of metallic ores, particularly of lead. In Derbyshire, where the different beds of limestone have been pierced through by the miners, the average thickness of the three uppermost is about 160 yards; the beds are separated by beds of trap or basalt, resembling ancient lavas. The fourth or lowest limestone has not been pierced through. The three beds of limestone are distinctly stratified; the prevailing color is grey: some of the strata in the upper limestone bed, seem almost entirely composed of the fossil remains of encrinites. In the northern part of Yorkshire, and in Westmoreland and Cumberland, the beds of mountain limestone alternate with beds of greywacke slate, and coarse sandstone. In North Wales, and in Somersetshire, mountain limestone forms entire mountain masses of vast thickness, distinctly stratified; the strata often varying in color, and sometimes in the nature of their organic remains.

The beds of mountain limestone vary very much in different parts of England in their number and thickness; even the quality of the limestone of the same stratum sometimes varies much in the same mountain. At Llanymynah, a low mountain composed of this limestone, the quality of the limestone on one side of the hill is considered by the lime burners of the very best kind; while at a little distance the same strata are so impure, from an intermixture with sand and clay, that they cannot be used with advantage: but what is more remarkable, I have seen in this hill, a stratum of the best limestone, lying regularly between other strata, suddenly terminate, and a whitish calcareous marle occupy its place, and preserving the same degree of thickness, and the same direction. As these strata contain marine organic remains, and were deposited at the bottom of the ocean, we may suppose that a submarine current had prevented the limestone from extending further, and supplied its place by a deposition of clay, before the stratum above was deposited. In the former case, where the strata of good limestone become in some parts calcareous and impure, we may suppose that submarine currents carrying away particles of sand, had intermixed them with the calcareous depositions in one part, but not in another. Indeed this sudden change in the quality of the limestone, is so common in that part of Wales, that the workmen have given to it the expressive name of *Balk stone.* When I was first informed of the balk stone, and saw that it impeded the operations of the quarrymen, I expected to have found a dyke of basalt, and was surprised to observe a mass of stratified limestone of an impure quality, cutting through the best limestone like a thick wall, and left standing, the good limestone being worked away on each side of it. This wall of limestone was of a darker color than the rest; it contained the remains of encrinites. It is owing, I conceive, to irregularities in the deposition of the strata, from causes attending their original formation, that soft and irregular beds or masses of clay occur in mountain limestone, which have probably been washed out by subterranean currents of water, and formed excavations and caverns of considerable magnitude. Many instances might be cited of considerable streams, and even rivers, ingulphed in mountain limestone, and rising again at the distance of several miles. In the northern counties, these openings are called Swallow Holes. Mr. Farey has enumerated twenty-eight swallow holes, in the mountain limestone of Derbyshire.

It is in the lower beds of mountain limestone that enormous natural caverns frequently occur; such are the well known cavern near Castleton, and Pools-hole near Buxton in Derbyshire, and Yordas Cave under Whernside in Craven. Gordal Scar and Weathercote Cave in the same district, cannot properly be called caverns, as they are open to the day; but the latter was probably once a cavern, of which the roof has fallen in. In all these caverns, and others that I have observed in this limestone, there is a stream of running water, which is more or less copious in rainy or dry seasons; and I am inclined to believe that the caverns have been formed by the agency of water percolating through natural fissures, and in the lapse of ages excavating the softer or more broken parts of the rock. The prodigious force with which these subterranean streams rush through the openings of some of these caverns, after continued rains, suggests the probability of this mode of formation. The whole of that enormous mass of limestone in Craven, from Ingleborough and Whernside to Gordal, is intersected by perpendicular fissures, which are narrow at the top, and become wider as they descend, through which the water may be heard to run at a vast depth below. These unseen but ever-active streams are slowly but progressively wearing down the internal parts of these calcareous mountains, and depositing them in the sea.

The limestone of Derbyshire contains thick beds of trap or basalt. In one or two instances the Derbyshire trap has been observed to assume the columnar structure. Other beds contain cavities filled with calcareous spar: they are provincially called Toadstone, the amygdaloid of mineralogists. Some varieties have a near resemblance to lava, and were supposed by Mr. Whitehurst to have been forced between the beds of limestone when in a state of fusion. Were we to admit their igneous origin, a more natural supposition, I conceive would be, that they were formed at distant periods of time, by successive eruptions of submarine volcanos, when these mountains were covered by the ocean; for it cannot be doubted that they were once under the sea. From recent observations, we have reason to believe that the agency of submarine volcanos is very extensive. Probably many of the differences observed in volcanic products and basaltic rocks, were occasioned by the different circumstances to which they were exposed after their eruption, on dry land, or under the incumbent pressure of the waters of the ocean.

The upper transition or mountain limestone in England is particularly metalliferous; the principal ores are those of lead and zinc; they occur principally in veins. Nearly all the lead obtained from the English mines is found in the mountain limestone. Ores of copper occur in small quantities in this limestone.

Most of the fossil organic remains, both in the upper and lower transition rocks, are of genera that are not found in the secondary limestones. Some of the upper beds seem almost entirely composed of encrinites: madrepores and corallites occur abundantly in the middle part of this formation.

Quartz Rock.—Rocks composed entirely of crystalline grains of quartz, sometimes occur among primary and transition mountains. Certain causes appear to have operated locally, and separated the quartz and felspar of granite into masses of considerable size. The quartz rock in the county of Wicklow I observed to be formed of what is called *greasy quartz*, similar to that in numerous veins in the mica-slate, near its junction with granite in the adjacent mountains, and is probably cotemporaneous with the veins. According to Dr. MacCulloch, the quartz rock in many parts of the Highlands presents evident indications of being composed of fragments and rounded pieces again united, and is in fact a quartzose greywacke or grit. Part of the Lickey Hill near Bromsgrove is composed of granular quartz; and similar beds occur near the village of Hartshill, in Warwickshire, between Atherstone and Nuneaton. Quartz rock, as distinguished from quartzose gritstone, is an inconsiderable formation, and may with more propriety be referred to the Transition, than the Primary Class.

Jasper.—This mineral is of rare occurrence as a constituent part of beds, or of mountain masses; it differs little from a siliceous flinty slate, but is generally coloured red, brown, or yellow, and is opaque. It contains a large portion of the oxide of iron in its composition. The beds of shale in the coal strata are sometimes converted by fire into a substance in every respect resembling jasper. There are beds of jasper of considerable magnitude in some parts of the Appenines covered by rocks of serpentine. In some situations beds of slaty jasper alternate with slate, to which rock they appear to bear the same relation as flinty slate. Lydian stone, which is a black siliceous flint slate, is by some geologists called black Jasper. The only bed of jasper that I have seen among the English rocks, occurs associated with beds of manganese ore at Doddiscombleigh in Devonshire. Jasper sometimes occurs in veins, and forms nodules in basaltic rocks.

Hornblende rock and *Greenstone.*—Hornblende rock has been described as associated with primary rocks, it also occurs in the lower transition rocks. Transition hornblende presents no variety of character by which it can be distinguished from Primary. Greenstone composed of felspar and hornblende, in which the felspar is white, and sienitic greenstone, in which the felspar is red, sometimes occur in beds among transition rocks, particularly of slate. But more frequently rocks of greenstone, sometimes called Trap, occur in an unconformable position, covering rocks both of the transition and secondary class, and will be described in the chapter on Unconformable Rocks; after the description of the lower secondary strata containing coal.

OBSERVATIONS ON CONFORMABLE TRANSITION ROCKS.

The order of succession in conformable transition rocks is extremely variable, and the thickness of the same beds differs greatly in different situations. In one district we find a whole uninterrupted series of calcareous strata, forming entire mountains; and in an adjacent district the same series are widely separated by intervening beds of slate, greywacke, or sandstone; and many of the strata which occur in one place, will often be wanting in another. We have before observed, that calcareous transition strata are subject to sudden variations of quality in the same mountain; we cannot therefore be surprised, that in distant districts a great diversity should exist, both in the number and thickness of calcareous strata of the same formation; no single stratum can be regarded as an universal formation. In whatever manner the strata were deposited, the deposition has been interrupted by causes to us unknown, which have accumulated thick masses in one situation, and prevented their formation in other parts. With respect to beds composed chiefly of the fragments of older rocks, it is evident that the contiguity to rocks which were most easily disintegrated, would produce thicker beds of fragments in certain situations than in others, and that their formation must be local.

The organic remains found in transition rocks, belong almost exclusively to genera no longer existing, and which do not occur in the upper secondary strata. Vegetable remains are rare in transition rocks; they occur sometimes in slate rocks. The trilobite is peculiar to transition rocks; the gigantic species occurs in slate, and the smaller species in limestone. The orthoceratite is chiefly found in transition limestone; univalve shells rarely occur in it. The prevailing fossils in this class are madrepores, corallites, and encrinites. The remains of vertebrated animals are rarely, if ever, found in transition rocks. Many instances cited by foreign geologists of vertebrated animals found in this class of rocks are erroneous; the rocks in which they occur belong to the secondary strata. And it should be known, that some English conchologists have described fossil remains from specimens collected in particular counties, without knowing precisely their true localities, or whether they were found *in situ* or in diluvial deposits. In the near vicinity of the transition limestone in Derbyshire, I have collected gryphites and numulites, and even the fossils of the chalk formation, but they had no relation to the ancient limestone; they were found in beds of gravel.

Conformable transition rocks cover the primary, and sometimes alternate with them; they are also associated with the lowest beds of the coal formation, so that no well marked division can be traced between them: but there is one character, independent of all artificial arrangements, which serves to distinguish transition rocks from the upper secondary strata, in countries where the regular coal formation is found. All rocks under the coal formation belong either to the transition or primary class; and all the strata above the coal formation, belong either to the upper secondary or the tertiary class. The geological position of the regular coal formation thus serves as a simple and intelligible key to the geology of all countries where the coal formation occurs. But where the coal strata are absent, the difficulty of determining the class to which certain rock formations belong, is often very great. Of this we have a striking instance in the perplexed attempts of foreign geologists to classify the vast calcareous formations of the Jura, and the outer range of the Alps; and the perplexity is further increased, by the mistakes which are made in referring to the English mountain limestone, by confounding it with the *calcaire alpin* or alpine limestone. The alpine limestone, according to some geologists, is a transition limestone; but according to other geologists, it is analogous to the magnesian limestone under the new red sandstone, and also comprises the lias limestones and the oolites. Indeed, I am convinced that in the vicinity of the Alps, rocks analogous to the chalk formation, have not unfrequently been classed with transition limestones. These mistakes have arisen from a desire to make observations agree with preconceived theories, and the artificial arrangements which Werner had invented. Thus it was taken for granted, that the granitic mountains of the Alps being primary, the calcareous mountains must be primary also; and when organic remains were first discovered in them, the geologists in France were greatly surprised, and seemed unwilling to admit the fact; at length, by a painful and reluctant effort, they removed all these mountains from the primary to the transition class. A more Herculean labour remains to be performed,—that of removing many of these mountains still higher, into the upper secondary class. In the vicinity of Moutiers in the Tarentaise, where M. Brochant first observed some organic remains supposed to belong to transition rocks, I discovered the Patella and other fossils, peculiar to the upper secondary strata.

In parts of France at a distance from the Alps and the Jura, the mineral character of the secondary strata might alone serve to identify them with the English lias, oolites, and chalk; but in the range of the Jura and the outer ranges of the Alps, the calcareous formations are of such immense magnitude, and the beds are often so highly indurated and crystalline, that it is only from their relative position and imbedded fossils that we can trace their analogy to the English strata, or to the secondary strata in the north of France.

CHAPTER VIII.

ON THE LOWER SECONDARY STRATA COMPRISING THE REGULAR COAL FORMATION.

The relative Geological Position of Coal Strata.—Wood Coal.—Mineral Coal.—Arrangement of the Strata in Coal-fields.—Concavities or Basins in which Coal Strata are deposited.—Intersections by Faults or Dykes.—Their Effects on Water in Coal Mines.—Peculiar Positions of Coal Strata in certain Districts.—On the mode of Searching for Coal.—Ironstone accompanying Coal.—Precautions necessary in the establishment of Iron Furnaces.—On Carbon as an original constituent part of the Globe.—On the Origin of Coal and its Deposition in Freshwater Basins or Lakes.—Experiments of Dr. MacCulloch on the Conversion of Vegetable Matter into Coal.—On imperfect Coal Formations beyond the limits of the regular Coal Strata.—Hints to Landed Proprietors respecting the probability of finding Coal and Rock Salt in Districts where they are at present undiscovered.—Coal Mines in France, &c.—On the Consumption of Coal in England, and the period when it will be exhausted.

It has been stated in the preceding chapter, that the upper conformable transition rocks are frequently associated with the lower series of secondary strata; so that from their position and mineral characters alone, no well marked line of division could be drawn between them; there is however a truly remarkable difference in the nature of the organic remains in the transition rocks, and in the lower secondary strata. In the transition series, the organic remains are almost exclusively those of marine animals, which are believed to have lived in the deepest parts of the ocean. In the lower secondary strata covering the transition rocks, the organic remains belong almost exclusively to the vegetable kingdom, and are analogous to the native plants of warm or tropical climates. These strata also contain much carbonaceous and bituminous matter, and frequently alternate with regular beds of coal.

The striking change in the nature of these organic remains, from marine animals to vegetables, marks that a great revolution had taken place in the condition of our present continents, after the formation of the mountain limestone, and before the deposition of the coal strata. To whatever causes we are to attribute this change, it has also been attended with another effect not less remarkable: after this period the formation of metallic veins appears to have almost entirely ceased, for they very rarely shoot up into the secondary strata which alternate with the principal beds of coal.

We have a remarkable instance of this change from animal to vegetable remains in the prevailing rocks of some of the northern counties. The mountains of transition limestone which extend through the Peak of Derbyshire, and through Craven in Yorkshire, abound exclusively with the organic remains of marine animals. They are covered on the eastern side by two thick beds, which contain carbonaceous and bituminous matter and vegetable impressions. The lowest is from one hundred and fifty, to one hundred and seventy yards in thickness. It is called by Mr. Farey* Limestone Shale, because it occurs over limestone. It is composed principally of thin strata of shale and sandstone. Where it is exposed to the air, it is of a dark reddish-brown color; over this lies a bed of coarse-grained siliceous sandstone, not less than one hundred and thirty yards in thickness. It has been called Millstone grit by Mr. Whitehurst and the miners in the north of England, from being used for the purposes of millstones. These two beds separate the metalliferous limestone from the coal strata in that part of England; for, though thin seams of coal sometimes are met with in them, they do not contain any of sufficient thickness to be worked. In the counties of Northumberland and Durham, the separation between the strata containing animal remains, and those which contain exclusively vegetable remains, is not so distinctly marked. In the lower part of the great series of strata of micaceous sandstone, shale, gritstone, and coal, which together comprise the coal formation of those districts, there are some beds of limestone, and a few seams of imperfect coal under the limestone; but the upper part of this series, to the depth of nearly one thousand feet, contains organic remains belonging almost exclusively to the vegetable kingdom.

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* Farey's Derbyshire.

Coal is a mineral too well known to require a particular description. Mineralogists divide coal into two species,—Brown coal, and Black coal; the former, sometimes called wood coal, is found chiefly in diluvial or in alluvial ground. It contains, besides charcoal and bitumen, various vegetable principles, and the branches or trunks of trees partially decomposed, which mark the origin of this kind of coal.

Black coal, or common coal, is composed of charcoal, bitumen, and earthy matter. The latter forms the ashes which remain after combustion: these vary in proportion in different coals, from two to near twenty per cent. The proportion of bitumen varies from twenty to forty per cent., and the charcoal from forty to more than eighty per cent.

Mineralogists have enumerated many different kinds of black coal: several of these pass by gradation into each other in the same mine. The most important varieties in an economical view are the hard coal, like that of Staffordshire, and bituminous or caking coal, called in London sea coal.

Black, or common coal, occurs in regular strata, which vary in thickness from a few inches to several feet or even yards. Many strata of coal often occur under each other, separated by strata of indurated clay, micaceous sandstone, coarse gritstone, ironstone, and soft bituminous slate called shale, and loose stones and clay called rubble. The series of strata which occur in one situation is denominated a coal-field.

Every district has its peculiar series of strata unconnected with any other: hence, the series of stratified coal have been denominated independent coal formations.

Coal-fields are of limited extent, and the strata frequently dip to a common centre, being often arranged in basin-shaped concavities, which appear to have been originally detached lakes, that were gradually filled by repeated depositions of carbonaceous and mineral matter. In some of the larger coal-fields, the original form of the lake cannot be traced, but in the smaller ones it is distinctly preserved.

The different strata under a bed of coal are frequently similar to the strata over it; and the same series is again repeated under the lower beds of coal, and sometimes with a perfect similarity both in the succession and thickness of each. In some instances a single bed of stone, of vast thickness, separates two beds of coal. In other instances, only a very thin stratum of shale or clay lies between coal beds.

Though numerous beds or seams of coal occur in one coal-field, very rarely more than three of these are worked. The thickness of the coal strata in the same coal-field often varies from a few inches to several yards; but each stratum generally preserves the same thickness throughout its whole extent. Instances to the contrary sometimes occur, in which the same bed will become narrower or wider, and sometimes be divided by a stratum of incombustible earthy matter, in different parts of its course. Few beds of coal are worked at a great depth which are less than two feet in thickness. The stratum lying over a bed of coal is called the roof, and the stratum under it the floor. The facility of getting coal depends very much on the compactness of the stone which forms the roof, not only on account of the security from falling, but for keeping out the upper water and preserving the pit in a dry state. The great expense incurred in supporting the roof when it is loose, frequently prevents a valuable bed of coal from being worked, or absorbs all the profit. In some situations the roof is indurated clay, impregnated with bitumen and pyrites. When this falls down, and is intermixed with water and small coal at the bottom, it takes fire spontaneously; on which account the miners close up the space with common clay, where the coal has been worked, to prevent the access of air to the combustible matter. This kind of combustible clay is called *tow;* it is common in the Ashby-de-la-Zouch coal-field, and in Staffordshire. The floor or stratum on which the coal lies, consists of clay in various degrees of induration, and is almost always of that kind which will resist the action of fire, called fire-clay, suited for furnace bricks and crucibles. (See Mr. Farey's Derbyshire, p. 179.)

It has been before observed that coal strata are frequently bent in concavities, resembling a trough or basin, dipping down on one side of the field and rising on the other. In Plate 4, fig. 2, the section of a coal-field is represented, in which the coal strata C C D D[*] are inclined in this manner, but partially dislocated by a fracture or fault at *f*. The extremities of the lowest stratum C C are several miles distant in some coal-fields, in others not more than one mile.

In the great coal-field or basin in South Wales, the strata are arranged in this manner over an extent of nearly a hundred miles in length, and a variable breadth of from five, to twenty miles. It is partly broken into by Caermarthen Bay, but it forms an extent of surface exceeding twelve hundred square miles. It contains twenty-three beds of workable coal, which are said by Mr. Martin to make together ninety-five feet in thickness of this valuable mineral; this will yield sixty-four million tons of coal per square mile. The thickest bed of coal is nine feet; in some parts there are sixteen seams of ironstone. The strata of this vast coal-field are deeply cut through by valleys, and are much broken by faults, and the quality of the coal varies greatly in different parts of the field.

At the Clee Hills in Shropshire, the breadth of some of the coal fields is not a mile. At Ashby Wolds in Leicestershire, in the central part of the fields at *e*, Plate 4, fig. 2, the main bed of coal is worked at the depth of two hundred and forty yards; but by the bending and rise of the strata, the same bed comes to the surface at C, about three miles distant. The depth of coal strata is very different in different situations, and, from the inclination or bending of the strata, differs much in the same district, as will be evident from what has been stated, and from an inspection of the last-mentioned figure. Some coal-fields extend in a waving form over a district.

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[*] The reference to the plate and figure is correct, but the lettering is omitted in the English copy, and the omission was not discovered in time to correct it in this edition.—*Am. Ed.*

On the eastern side of England, the strata generally decline, or, in the miners' language, dip to the south-east point: on the western side, the strata are more frequently thrown into different and opposite directions, by what are called faults and dykes.

A Fault is a break or intersection of a series of strata, on one side of which they are raised or thrown down; so that in working a bed of coal, the men come suddenly to its apparent termination. A Dyke is a wall of mineral matter, cutting through the strata in a position nearly vertical. The name *dyke* is originally derived from our Northern neighbors; it signifies a wall. The thickness of dykes varies from a few inches, to twenty or thirty feet, and even yards. The dykes which intersect coal strata are composed of indurated clay, or more frequently of basalt, and will be particularly described in the following chapter. In some coal-fields the strata are raised or thrown down on one side of a dyke one hundred and fifty yards or more; and the miner, after penetrating through it, (see Plate 4, fig. 3,) instead of finding the same coal again, meets with beds of stone or clay on the other side, at *e*: hence he is frequently at a loss how to proceed in searching for the coal which is thus cut off. If the stratum of stone *e* be the same as any of the strata which were sunk through in making the pit or shaft *g g*,* it proves that the bed of coal is thrown down on the side of the fault at *e*, and he can determine the exact distance between that stratum, and the coal he is in search of. But if the stone is of a different kind from any which was above the coal *c c*, he may be certain that the strata are raised on that side; but to what distance can only be ascertained by trial, if the under strata of the coal bed *c c* have not been previously perforated. It frequently happens, however, that two or more strata of stone or shale at different depths, are so similar in their quality and appearance, that it is impossible to distinguish them: in such cases it is necessary to perforate the stratum, to ascertain its thickness and examine the quality of the strata above or below it, by which its identity with any known stratum may generally be ascertained. The manner in which the strata are inclined towards the fault, will also determine whether they are thrown up or down, provided they are not shattered where they come in contact with it, which is frequently the case.* Each bed of coal in a coal-field has certain characters by which it may generally be known to be the same. Its thickness, and the quality of the roof and floor, with that of the upper and under strata, generally serve to identify it, though it may sink deeper in one place than another, and vary in distance from the surface five hundred feet.

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* *g g* omitted in the Plate.

The dykes which intersect coal strata are generally impervious to water; and it not unfrequently happens, that where the strata decline to them, they hold up the water and occasion springs at the surface, or keep the coal-works on that side of the fault under water, when the coal-works on the other side are dry. This will be better understood by referring to Plate 4, fig. 2 and 3, where the coal strata on the right hand of the faults decline or dip to them; and the water which passes through or between the strata will be stopped at the faults and held up, should any of the lower strata be also impervious, in which case the coal beds to the right of the fault will be under water, and those on the other side dry. Now should a perforation be incautiously made through the dyke, all the water will be thrown upon the works on the left, that were before dry. Where the wall on each side of a fault belongs to different proprietors, a few strokes with a pickaxe may thus do incalculable mischief to those on the one side, and render great service to the other, by laying their pits dry.

The deepest coal mines in England are those in Northumberland and in the county of Durham, some of which are worked nearly three hundred yards below the surface. The thickest bed of English coal of any considerable extent is the main coal in Staffordshire, which is thirty feet. The upper, lower, and middle parts of the bed differ in quality. Mr. Keir, who has written an interesting account of the mineralogy of the south of Staffordshire, says that thirteen different kinds of coal occur over each other in this bed; the uppermost, which is compact, serves as a roof in getting the under coal. At the Wood Mill-hill colliery in this county, the coal is said to be forty-five feet thick; and three beds of coal, from three to four feet in thickness, have been found under it, since Mr. Keir's account was published. The first is only two yards under the thick coal. The main bed of coal in the Ashby-de-la-Zouch coal-field is thirteen feet thick; the upper and lower seams of this bed also vary in quality; and the top serves as the roof, being more compact than the stratum over the coal. Few beds of coal in other parts of England or in Wales exceed from six to nine feet in thickness; but a difference in the quality may generally be observed in the upper, lower, and middle parts of the same bed.

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* If the dyke make an acute angle with the upper surface of the strata, they are thrown up on that side; but if it make an obtuse angle, they are thrown down. See Plate 4. fig. 2. d; and fig. 3. d.

A curious fact is stated by Mr. Keir respecting the main coal of Staffordshire:—In one situation the upper part of the bed separates from the lower, and rises to the surface, or crops out. It is at first divided by indurated clay called bind or clunch; but as the distance becomes wider, the intervening stone grows harder, and will strike fire with steel. Similar separations take place sometimes in the beds of coal in the mines of Northumberland and Durham. The largest known bed of coal in the west riding of Yorkshire is near Barnsley: it is ten feet thick, and is supposed to be formed by the meeting of two or more seams, which soon separate again. The miners have not been able to trace the same bed in situations where it might have been found, had it preserved the same thickness in other parts of its course.

Coal strata, beside the more common dislocations by faults, present remarkable contortions which it would be difficult to explain, except by admitting a lateral force, which has compressed them into a zig-zag form. To the same cause, or perhaps to a partial sinking of the earth, we may attribute the origin of what is called *faulty ground*, which frequently occurs in coal-fields. In this, no actual dyke appears to have been formed; but the beds of coal with all the accompanying strata are so broken and shattered, that no workings can be carried on, till the miner has got through them into regular strata. These broken parts of the strata, called *troubles* and *faulty ground*, occasion much more difficulty to the miner than common faults or dykes, and are sometimes of great extent.

In some coal-fields one part of a stratum is inclined, and the other part vertical. A curious fact of this kind may be seen in a small coal-field near the town of Manchester.*

The position of coal strata in many coal-fields may be represented by a series of fresh water muscle shells, decreasing in size, laid within each other, but separated by a thin paste of clay. If one side of the shell be raised, it will represent the general rise of the strata in that direction; and if the whole series be dislocated by partial cracks, raising one part a little, and depressing the other, to represent faults in the coal, it will give a better idea of the coal-field than any description can convey. We are here to suppose that each shell represents a stratum of coal, and the partitions of clay the earthy strata by which they are separated. The outer shell represents the lowest bed of coal, which may be many miles in extent. Now if a much larger shell be filled with sand, and the lowest shell be pressed into it, we may consider the large shell to represent limestone, and the sand gritstone; we shall then have a model of the coal strata in many parts of England, and their situation over the metalliferous lime, with the beds of sandstone by which they are separated from it.

From the inclination or bending of coal strata, they always rise near to the surface in some parts of their course, and would be visible if not covered by soil or gravel. In the intersections formed by rivulets, or by accidental fractures on the sides of hills in a district, the nature of the strata may often be determined, and should be ascertained before any expense be incurred in boring or sinking for coal. When this is done, a proper station should be chosen; which requires great judgment: otherwise it is possible to bore or sink to great depths, and miss a bed of coal which exists very near the place: this will be evident from the inspection of the two stations, *a* and *b*, Plate 4, fig. 2: in the latter it would be impossible to meet with the bed of coal, c, because the search is made beyond the line where it rises to the surface, or, in the miners' language, crops out. At *a*, coal would be found after sinking only a few yards. In most situations, it is better to search for coal, as deep as can be done without expensive machinery, by sinking a well in preference to boring. By sinking, a decisive knowledge of the nature and thickness of the strata can be ascertained as far as you descend, which can be only imperfectly known by boring; for the latter mode is liable to great uncertainty of result, from bendings or slips of the strata. If, for instance, the borer be worked in the situation *a*, Plate 4, fig. 2, it will pass through a great depth of coal, which in reality may not be more than a few inches in thickness. Besides the uncertainty of the results, the grossest impositions are sometimes practised to answer interested purposes, and induce proprietors to continue the search, where there is no reasonable probability of success. Where coal strata come to the surface, they are generally in a soft decomposed state, and intermixed with earthy matter. They frequently present no appearance of coal, but the soil may be observed of a darker color. The real quality of the coal cannot be ascertained until it is found below in its natural undecomposed state, lying between two regular strata of stone, or indurated clay. In general it is observed that the same bed improves in quality, as it sinks deeper into the earth. Coal strata are generally split or divisible into rhomboidal blocks, by vertical joints, which range about E. S. E. and W. N. W.: these are called slines; the oblique shorter joints are called cutters.

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* I have given a short account of this coal-field in the second volume of the Transactions of the Geological Society.

From what will be stated in the subsequent chapters, it will appear that there is more than one-third of England in which all search for valuable coal is useless: the knowledge of a negative fact becomes important, when it saves us from loss of time, expense, and disappointment.

Coal strata are frequently accompanied by thin strata of ironstone. This stone has a dark-brown or grey colour, and has an earthly appearance and fracture, and is about three times heavier than an equal bulk of water. Some kinds have the specific gravity of 3.6. Though modern mineralogists call this mineral clay-ironstone after Werner, from its resemblance to argillaceous stones,—on analysis it is found to contain but a very minute portion of alumine or pure clay, sometimes not more than two per cent. It is composed principally of iron combined with oxygen, carbonic acid, and water, and a small quantity of silex, and in some instances with calcareous earth. If it be of a good quality, it yields more than thirty per cent. of iron. In some of the beds of clay over coal, detached nodules of ironstone occur, which are also smelted for iron.

The vast extent and importance of our iron-works are well known, but their establishment is of recent date. Formerly our furnaces were on a diminutive scale, and wood or charcoal was the only fuel employed; but in the present cultivated state of the country, wood could not be procured in requisite quantity. The application of coal or coke to the smelting of iron is among the most useful of modern improvements; but it is only some kinds of coal that are proper for the purpose. Inattention to this circumstance has frequently led landed proprietors to great and unprofitable expense. Finding ironstone and coal in abundance upon there estates, they have constructed furnaces and other works at a considerable cost, and have discovered too late that the coal, however suitable for domestic or other uses, was unfit to make iron of a marketable quality. To make good iron from the best ironstone, it is necessary that the coal should be as free as possible from every substance with which sulphur is combined. It should possess the property of forming a hard coke or cinder; and if it have the quality of cementing or caking, it is the more valuable, as the small coal can be used for the purpose of coking, which is frequently wasted where it does not possess this quality.

Different opinions have been formed respecting the origin of coal. In the primary and transition mountains, a particular species of coal occurs in small quantities, which is extremely hard and splendent, and burns without smoke or flame, and is called by mineralogists Anthracite*, and it clearly resembles, and appears to pass into the mineral called plumbago or graphite. Common coal also sometimes graduates into plumbago. Plumbago and anthracite are so completely mineralized as to present no external indications of a vegetable origin; but the strata over common coal abound in vegetable impressions, and the cortical part of the vegetable is frequently seen converted into mineral coal. It is not often that vegetable impressions are found in the coal itself but some of the regular coal beds in the Dudley coal-field, of which I have specimens of considerable size and thickness, are composed of distinct layers of vegetables converted into true mineral coal; but when separated, preserving the distinct cortical impressions of plants throughout the whole thickness of the coal: and it is reasonable to believe, that all the coal beds in the same field are also formed of similar plants, though the vegetable impressions may be effaced. Granting that common coal is originally derived from the partial decomposition of *vegetables*, it may be fairly asked,—from whence did the vegetable tribes originally derive the carbon of which their solid parts are principally composed? Carbon either previously existed in nature, or trees and plants had the power of forming it from more simple elements. Neither of these opinions is improbable, nor are they at variance with each other. If carbon be a compound substance, of which hydrogen is a constituent part, it may be formed by the process of vegetation, or it may exist also in the mineral kingdom, independently of organic productions. That carbon is an original constituent elementary part of the globe, can scarcely be doubted, when we consider that united with oxygen it is an important constituent part of all limestone mountains, composing nearly one half by weight of their substance, or 44 of carbonic acid to 56 of lime. Now the quantity of carbon when separated from the oxygen, would be equal to one-eight of the whole mass of limestone; and as all the ancient limestone formations were deposited under the ocean, we cannot suppose that this carbon was derived from the vegetable kingdom. Could the carbon be separated from the limestone in the great calcareous ranges of the Jura and the Alps, it would form a bed of pure carbon, nearly a thousand feet in thickness, through the vast extent of these mountains: and were we forced to admit that this carbon was derived from organic secretion, we should rather look to the animal than the vegetable kingdom for its origin; as no small portion of many calcareous mountains is composed of animal remains, and calcareous beds are forming in our present seas of great extent and thickness, by the accumulation of shells and coral.

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* It is abundant in Pennsylvania and Rhode Island.—*Am. Ed.*

Bitumen, which is composed of carbon and hydrogen, is known to exude from the lava of recent volcanos; and the volcanic tufa in Auvergne, which covers a vast extent of surface, is almost every where intermixed with bitumen. In hot weather I have seen it trickling out of the tufa in considerable quantities, resembling melted pitch. As the ancient volcanos of that district broke out from beneath the granite, we may fairly infer that the bitumen which abounds in the volcanic tufa is as much a mineral substance as the sulphur which accompanies volcanic eruptions, or which is sublimed from the vapours of quiescent volcanos.

Though the carbon in primary mountains may be derived from the mineral kingdom, there can scarcely remain a doubt, that wood-coal and common coal are of vegetable origin. Wood-coal, or brown coal, is found in low situations, and appears to have been formed of heaps of trees buried by inundations under beds of clay, sand, or gravel. The woody parts have probably undergone a certain degree of vegetable fermentation, under the pressure of the incumbent earthy matter, by which they have been carbonized and consolidated. In some specimens of this coal, the vegetable fibre or grain is perceptible in one part, and the other part is reduced to coal. The vegetable principles which this coal contains, united with bitumen and charcoal, have been already stated. In black or common coal, the vegetable extract and resin are destroyed, and the charcoal and bitumen alone remain; but wood-coal and common coal bear in other respects too close a resemblance, to allow us to ascribe to them a different origin, though they were probably formed from different tribes in the vegetable kingdom, and under different circumstances.

Wood-coal is found in considerable quantities at Bovey Heathfield, near Exeter. Several beds of coal are separated by strata of clay and gravel: the lowest is seventeen feet thick, and rests on a bed of clay, under which is sand resembling sea sand. The coal in contact with the clay has a brown colour, and appears intermixt with earth. In other parts the laminæ of the coal undulate and resemble the roots of trees: in the middle of the lowest stratum the coal is more compact, and is of a black colour, and nearly as heavy as common coal.

A great repository of this kind of coal exists near Cologne: it extends for many leagues: it is fifty feet in thickness, and covered with a bed of gravel from twelve to twenty feet deep. Trunks of trees deprived of their branches are imbedded in this coal; which proves that they have been transported from a distance. Nuts, which are indigenous to Hindostan and China, and a fragrant resinous substance, are also found in it. A similar resinous substance occurs in the Bovey coal, and was discovered with fossil wood in cutting through Highgate Hill. Mr. Hatchett, by whom it was analysed, has given it the name of retinasphaltum.

In wood-coal we may almost seize nature in the fact of making coal, before the process is completed. These formations of coal are of far more recent date than that of common coal, though their origin must be referred to a former condition of the globe, when the vegetable productions of tropical climates flourished in northern latitudes. The vegetable origin of common mineral coal appears to be established by its association with strata abounding in vegetable impressions, by its close similarity to wood-coal, (which is undoubtedly a vegetable product,) and lastly, by the decisive fact, that some mineral coal in the Dudley coal-field, is entirely composed of layers of mineralized plants.

But though the vegetable origin of mineral coal may be satisfactorily established, there is considerable difficulty in conceiving by what process so many beds and seams of coal have been regularly arranged over each other in the same place, and separated by strata of sandstone, shale, and indurated clay. It will tend to simplify the inquiry, if we examine a coal-field of very limited extent; such as those which occur in small coal-basins called *swilleys* on the hills in the west riding of Yorkshire, and which are not more than one mile in length and breadth. It seems evident that these basins have once been small lakes or marshes, and that the strata have been deposited on the bottom and sides, taking the concave form which depositions under such circumstances must assume: and it is deserving notice, that the stratum of coal which in one of these coal-basins at Hudswell is a yard thick in the lowest part, gradually diminishes as it approaches the edges, and then entirely vanishes. This fact proves that the present basin-shaped position of the strata was their original one; and that the basin at the period when the coal strata were formed, was a detached lake or marsh, and not part of the bed of the sea.

It has been supposed that coal strata were deposited on the bed of the ocean; but this is not probable, for many of the vegetable species whose remains are found in these strata, are of marsh plants; and some of the species of ferns are land plants, and probably grew on dry land surrounding the coal-basins when they were lakes.

There is also a stratum of imperfect ironstone or highly indurated shale in the Yorkshire and Derbyshire coal-fields, called *Musclebind*, which is filled with shells resembling freshwater muscles: and though there may be shells closely allied to them in form, in some of the marine limestones, it deserves notice, that the substance of the shells in the coal shale, at least wherever I have seen them in the Northern coal-fields, has that cretaceous or chalky appearance and consistence, which I have observed to be peculiar to shells in what are regarded as undoubted freshwater formations.

If the basins in which the coal strata are deposited were originally freshwater lakes or marshes,—did the plants whose remains compose coal, grow where the coal is now found? or were they carried by rivers or inundations into the lakes, and gradually deposited as the water evaporated? The former is perhaps the most probable hypothesis; as there is reason to believe that the vegetables were principally species of reeds or aquatic plants: and the occurrence of the same peculiar kind of fire clay under each bed of coal, favours the opinion, that this was the soil proper for the production of those plants from which coal has been formed. If we suppose that these lakes were periodically laid dry, and again filled by sudden inundations, we shall have the conditions required for the succession of carbonaceous and earthy strata that take place in a coal-field: a repetition of such inundations would fill up the lake or basin. Nor can such a supposition appear improbable; for as the species of plants whose remains are found in the coal strata are analogous to those of warm climates, we may infer, that in a former condition of the globe, these Northern latitudes had the temperature of tropical regions, and also the hot and rainy seasons which promote the rapid growth of vegetation, and occasion periodical inundations.

In large coal-basins, where the coal occurs in beds from nine to thirty feet in thickness, we can scarcely conceive it possible, that a mass of vegetable matter sufficiently large to form such beds, can have been collected in one season: these thick beds are, however, almost always divided by thin seams of clay. The thirty feet coal of Staffordshire is composed of thirteen different beds, which, having but thin partings, are regarded as one bed. The thirteen feet bed of coal at Ashby Wolds is composed of two or more beds of different qualities.

It is probable that some of the coal strata in large coal-basins have been formed by the accumulation of vegetable matter carried down by inundations, and gradually deposited in the bottom of lakes. Very thin seams of coal sometimes alternate with the shale lying between two large beds of coal. I have on the table before me, a mass from the Dudley coal-field, in which part of two beds of coal are separated by a stratum of indurated clay or shale about two inches in thickness; and this stratum of shale contains more than twenty seams of coal, none of which exceed the thickness of a wafer, but the coal seams are distinctly separated from each other by seams of shale. These thin seams of coal and shale were probably formed by the alternate deposition of leaves or minute aquatic plants floating on the water, with the earthy particles mechanically suspended in it. In very large coal-fields, the original form of the basin or lake in which the strata were deposited, is sometimes nearly effaced by faults and dislocations, which have raised or cast down the strata several hundred feet; but in the smaller basins or coal-fields, the original form is often distinctly preserved.

The plants whose remains are found in coal-fields possess little ligneous internal matter, but appear to belong chiefly to species of reeds and succulent vegetables; the stems of the larger plants being either pressed flat, or filled with sandstone, ironstone, or indurated clay, without any vestige of organization except the pith, the form of which is preserved in many of the large stems. In some places, where sections are made in sandstone strata accompanying coal, instances of fossil stems of large plants occur in a vertical position. In Burntwood quarry at Althouse, near Wakefield in Yorkshire, several vertical stems of large magnitude have been found. One stem which I measured in the quarry was nine feet in length and ten inches in thickness; but what is remarkable, this stem cut through three strata of sandstone, parted by regular strata seams: it had therefore probably grown in the situation where it stood; for it is difficult to believe that any vegetable stem could pierce through three strata of sandstone, the lower of which at least must have been partly consolidated. This fact further proves, that the strata were deposited rapidly, before the decomposition of the stem could be effected.

The difficulty in explaining the conversion of vegetable matter into coal, has been in a great measure removed, by the luminous observations and experiments of Dr. MacCulloch, on wood in its different states of bituminization, from submerged wood, to peat, brown coal, surturbrand, and lastly to jet, in which the traces of organization are nearly destroyed. These substances, which have been only subjected to the action of water, all yield bitumen by gentle distillation: but they differ from mineral coal, by yielding also a large portion of acetic acid, which marks the remains of undecayed vegetable substances. Common coal has formerly been regarded as a combination of charcoal with bitumen; but as bitumen is itself a combination of carbon with hydrogen, Dr. MacCulloch says, it will be more proper to consider coal as a bitumen, varying in its composition from the fattest Newcastle coal to the driest Kilkenny coal, and owing its compactness to the peculiar circumstances under which it has been formed, the changes it may have subsequently undergone, and the substances intermixed with it. The power of yielding naptha by distillation, is the distinction between one end of the series and the other. The last link (anthracite,) contains only carbon; so the last result of the distillation of asphaltum is also carbon.

To convert wood-coal or jet into true coal, some further process than long submersion in water seems necessary. The latter substance, jet, was reduced to powder, and put into a gun-barrel and covered close with Stourbridge clay; it was then exposed to a moderate red heat. By this process, it was converted into a substance having all the external characters and chemical properties of true mineral coal, and the clay was converted into coal shale. But though in the laboratory of the chemist the last stage of the formation of coal requires artificial fire, yet in the great laboratory of Nature, vegetable fermentation and compression, may evolve sufficient heat for the ultimate formation of mineral coal. It may however deserve notice, that most great repositories of coal are intersected by beds and dykes of basalt, which is now admitted to be of igneous origin.*

Pressure and time alone may be sufficient to produce the destruction of vegetable organization, and the perfect consolidation of beds of coal, as is proved by the complete consolidation of loose materials left in coal mines, when the supports are removed and the upper strata sink down. In a few years scarcely a trace of former operations remains. In contemplating natural causes, we are too apt to measure their power by the results of artificial processes, and by observations continued for a short portion of human life. The substances found in the neglected vessels of the chemist, often prove to us that changes in the physical properties of bodies are effected by time, which it would be difficult to imitate in common experiments.

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* At Meisner in Hesse, a thick bed of wood-coal or lignite is covered by an enormous mass of basalt, and is only separated from it by a thin bed of clay. The upper parts of the lignite are converted into anthracite and even into true bituminous coal, while the lower parts are formed of earthy and fibrous wood-coal.

The great coal formation appears to be confined to the lower secondary strata, generally resting on transition limestone. In some situations, the under transition rocks are wanting, and the series of coal strata rest on granite, with the intervention of a thick bed of conglomerate. No mineral coal, both good in quality and abundant in quantity, has ever been found either in the primary or in the lower transition rocks, or in the upper secondary or the tertiary strata. It is true, that in the oolite of the upper secondary strata, some strata of imperfect coal occur on the eastern moorlands of Yorkshire, which are thought of sufficient importance to be worked; but the coal is very indifferent, and is chiefly used by the lime-burners. The Kimmeridge-clay in the oolites, also contains beds of shale impregnated with bitumen, which is used as fuel in a country where coal is extremely dear. The wood-coal of Bovey Heathfield has been already noticed. I may state, in addition, that I visited the mine in 1815: it is worked like an open quarry; it had been for some years previously under water, but was then laid dry by pumps. There are several irregular beds of lignite or wood-coal alternating with what is called dead coal, which is less inflammable, and resembles a bituminous shale; the beds wedge out narrow as they descend. The whole mass is more or less bituminized: but the upper part, which preserves the woody structure more perfectly, seems principally composed of clay. Sulphate and carbonate of iron occur in some part of the beds, and rounded pieces of maltha. Wood-coal occurs chiefly in diluvial deposits. Where wood-coal occurs with overlying basalt, it is converted into a substance more nearly resembling mineral coal. This has been called by the German geologists the floetz trap formation. This coal occurs in Iceland, in the north of Ireland, and in many basaltic districts on the continent. Before concluding this brief account of imperfect coal formations, out of the limits of the regular coal formation, I would direct the attention of geologists to two situations, in which coal is found, that are well deserving of notice. The first is the mine of Entreveines, situated in a mountain valley about 2000 feet above the lake of Annecy, and at least 3500 feet above the level of the sea. The bed of coal consists of three minor beds, separated by thin seams of clay varying in thickness, yielding about four feet of good coal, which has the character and fracture of mineral coal; it is shining, does not soil the fingers, and is highly bituminous, being exclusively used for the gas lights in the cotton mills at Annecy. The total thickness of the sandstone shale and coal strata, which compose the coal formation in this place, is about one hundred and fifty yards; they are placed between thick beds of limestone, and dip together at an angle of about seventy degrees. It is worthy of observation, that the limestone beds above and below the coal formation, have the hardness, fracture, translucency, and appearance of the transition limestone at Plymouth; yet in another part of the mountain, the same limestone is associated with a bed of dark clay, containing gryphites and belemnites, clearly indicating that the bed was analagous to our lias or clunch clay; and that the limestone associated with it, notwithstanding its mineral character, belonged to the upper secondary strata; and hence that the coal, in geological position, agreed with the imperfect coal formations in the English oolites. Here then we have a further proof of what has before been stated, that in the calcareous formations of the Alps, the upper secondary strata lose the soft and earthy character which distinguish the oolites and chalk in England, and are converted into marble. The coal also, which is very imperfectly formed in the English oolite, has in the same limestone formation in the Alps, the character of true mineral coal. A still more remarkable coal formation occurs at Alpnach, near the lake of Lucerne in Switzerland, where a bed of coal is found at the depth of two hundred and eighty feet from the surface: over the coal, there is a stratum of-bituminous limestone containing fluviatile shells, and bones and teeth of the large mammalia, particularly the teeth of a species of mastodon. The specimens which were shown me by Professor Meissner of Berne, on my return from the Swiss Alps, made me regret exceedingly not having visited Alpnach. Notwithstanding the occurrence of the bones of large land quadrupeds in the stratum over the coal, the coal approaches in character nearly to mineral coal, and the strata of micaceous sandstone and shale above it, have a close resemblance to those in our English coal-fields: and though from the organic remains, we are compelled to place the coal of Alpnach among the tertiary strata, or to admit the occurrence of an anomalous formation like the one at Stonesfield, still I believe the true geological position of the coal of Alpnach is problematical; and it deserves the particular attention of some English geologist, well acquainted with the different coal-fields in his own country, and the lignite formations in different parts of Europe.

It will be seen by a reference to the Geological Map, and the Chapter containing an Outline of the Geology of England, that there is a considerable part of South Britain where coal has not been found. Two important questions may be asked;—do the coal strata extend under the parts where coal has not yet been discovered? And if they do extend beyond their present known limits,—what practicable means can be employed to obtain the coal? With respect to the first question—it is well ascertained by boring, that the coal strata do in some places extend under the magnesian limestone, by which they are immediately covered in some of the northern counties; though it was formerly supposed, that the coal terminated before it reached the magnesian limestone, or was there cut off by a fault. In a considerable part of England, the coal-fields are immediately covered by what is called the red marle or new red sandstone; but there are but few situations where the red marle and sandstone has been sunk through for coal. I am however decidedly of opinion, that under the red marle adjacent to the coal districts in my native county Nottinghamshire, the regular coal strata would be found; and that there is a high degree of probability, that rock salt or brine springs will be found in the red marle itself, particularly in those parts of the county where beds of massive gypsum occur. The same remark might be extended to the red marle and sandstone districts adjoining coal strata in Derbyshire, Leicestershire, and Warwickshire. In confirmation of the opinion here advanced, a saline spring has very recently been discovered about four miles north-west of Nottingham; and coal has been lately found under the red marle and sandstone on the south side of Charnwood Forest, where it had not before been suspected to exist. It may however be proper to say, that no search of this kind by boring should be undertaken by any one, to whom the expense in case of failure would be a serious inconvenience.

The dip and direction of the strata in the coal-fields nearest to the estate where the search is to be made, should be well known. If the strata dip towards the estate, it is probable the coal may extend under it: if they dip from it, the search should not be undertaken. To make this intelligible, see Plate 3. fig. 3. *a. a. a.* are a series of coal strata, or, as they are provincially called, coal measures, dipping toward the side B. *c. c. c.* are strata of red marle or sandstone, lying unconformably over the coal strata. Now according to this arrangement, a search for coal might be successful, though the bed might be at too great a depth to be worked. Whereas on an estate at D, as the coal strata dip from it, were we to bore to the centre of the earth, we could never find the beds 1. 2. 3. 4. If the estate B is situated a considerable distance from a known coal-field, the strata of coal may bend as represented Plate 4. fig. 2. and crop out before they reach the station where the trial is made; and as the outcrop is covered by the red sandstone, this cannot be known but by trial.

Rock salt or brine springs are most likely to be found in the vicinity of massive gypsum, without regarding the stratification. As for the districts where the upper secondary strata of lias, oolite, and chalk occur, all search for the regular coal strata must there be fruitless; as the vast thickness of these calcareous formations precludes the hope of success.

Coal mines, it is well known, are subject to fatal explosions of what is called the fire-damp, or carburetted hydrogen gas. This gas appears to be generated by the decomposition of iron pyrites in coal, and may often be heard issuing from the fissures in coal beds with a bubbling noise, as it forces the water out along with it. The choke damp, as it is called, is either carbonic acid gas, (fixed air,) or the unrespirable residue of air left after explosions, when all the oxygen is consumed. In the Appendix will be given some observations on the ineffective means hitherto adopted, to prevent the frequent recurrence of fatal accidents in coal mines.

The regular or great coal formation, has never been discovered at a very considerable elevation above the level of the sea: it generally is found towards the feet of great mountain chains, or in the valleys near to lofty mountain ranges. The geology of large portions of the globe is still unknown; but it appears from those parts with which we are acquainted, that coal is found principally in temperate regions, between thirty-five and sixty-five degrees of latitude. In Europe,—Great Britain, France, Flanders, and Germany, (particularly Silesia, Saxony, Bohemia, and Thuringia,) contain large coal formations; but in the southern and more northern parts of Europe, coal is of rare occurrence. In North America, coal is found in great abundance on the western side of the Alleghany mountains; near Pittsburg in Pennsylvania,* the beds of coal, I am informed, are of great extent, and are so nearly horizontal, that in one situation the bed of a river is formed for several miles in the same stratum of coal. Coal has been discovered in New Holland. The only great coal formations in Asia that we know of are in China, where coal is described as existing in large quantities, and as being extensively used for fuel in that vast empire.

As France will probably continue to be for many centuries our great manufacturing rival, it is interesting to know, what are her resources for the supply of an article found so essential to almost all the principal manufactures of Great Britain. Before the late peace, forty-seven of the departments contained coal districts, and the annual consumption was stated to be about five millions tons; but a great part of the rich and extensive coal-field, extending from Valenciennes to Aix-la-Chapelle, was comprised in that part of Flanders, which was separated from France at the peace. There are, however, extensive coal districts in the north-eastern, the western, the middle, and the southern parts of France. Two miles from Lyons there are coal mines; and the coal of St. Etienne, about twenty miles north-west of Lyons, is of the very best quality, and well suited for the manufacture of iron. In the year 1822, when I passed through that country, many English workmen were employed in the iron works, which were rapidly increasing. It cannot be doubted that France possesses every advantage, from its soil, its climate, and its mineral resources, which a great manufacturing nation can require.

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* Also near Richmond, Virginia; in Missouri, &c.—*Am. Ed.*

OBSERVATIONS ON THE PERIOD WHEN THE COAL MINES IN ENGLAND WILL BE EXHAUSTED.

Coal was known, and partially used, at a very early period of our history. I was informed by the late Marquis of Hastings, that stone hammers and stone tools were found in some of the old workings in his mines at Ashby Wolds; and his Lordship informed me also, that similar stone tools had been discovered in the old workings in the coal mines in the north of Ireland. Hence we may infer, that these coal mines were worked at a very remote period, when the use of metallic tools was not general. The burning of coal was prohibited in London in the year 1308, by the royal proclamation of Edward the First. In the reign of Queen Elizabeth, the burning of coal was again prohibited in London during the sitting of parliament, lest the health of the knights of the shire should suffer injury during their abode in the metropolis. In the year 1643, the use of coal had become so general, and the price being then very high, many of the poor are said to have perished for want of fuel. At the present day, when the consumption of coal, in our iron-furnaces and manufactories and for domestic use, is immense, we cannot but regard the exhaustion of our coal beds, as involving the destruction of a great portion of our private comfort and national prosperity. Nor is the period very remote when the coal districts, which at present supply the metropolis with fuel, will cease to yield any more. The annual quantity of coal shipped in the rivers Tyne and Wear, according to Mr. Bailey, exceeded three million tons. A cubic yard of coal weighs nearly one ton, and the number of tons contained in a bed of coal one square mile in extent and one yard in thickness, is about four millions. The number and extent of all the principal coal beds in Northumberland and Durham is known; and from these data it has been calculated, that the coal in these counties will last 360 years. Mr. Bailey in his Survey of Durham states, that one-third of the coal being already got, the coal districts will be exhausted in 200 years. It is probable that many beds of inferior coal, which are now neglected, may in future be worked; but the consumption of coal being greatly increased since Mr. Bailey published his Survey of Durham, we may admit his calculation to be an approximation to the truth, and that the coal of Northumberland and Durham will be exhausted in a period not greatly exceeding two hundred years. Dr. Thomson, in the Annals of Philosophy, has calculated that the coal of these districts, at the present rate of consumption, will last 1000 years; but his calculations are founded on data manifestly erroneous, and at variance with his own statements: for he assumes the annual consumption of coal to be only two million eight hundred thousand tons, and the waste to be one-third more,—making three million seven hundred thousand tons, equal to as many square yards; whereas he has just before informed us, that two million chaldrons of coal, of two tons and a quarter each chaldron, are exported, making four million five hundred thousand tons, beside inland consumption, and waste in the working.* According to Mr. Winch, three million five hundred thousand tons of coal are consumed annually from these districts; to which, if we add the waste of small coal at the pit's mouth, and the waste in the mines, it will make the total yearly destruction of coal nearly double the quantity assigned by Dr. Thomson. Dr. Thomson has also greatly overrated the quantity of the coal in these districts, as he has calculated the extent of the principal beds from that of the lowest, which is erroneous; for many of the principal beds crop out, before they reach the western termination of the coal-fields. With due allowance for these errors, and for the quantity of coal already worked out, (which according to Mr. Bailey is about one-third,) the 1000 years of Dr. Thomson will not greatly exceed the period assigned by Mr. Bailey for the complete exhaustion of coal in these counties, and may be stated at three hundred and fifty years.

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* The waste of coal at the pit's mouth may be stated at one-sixth of the quantity sold, and that left in the mines at one-third. Mr. Holmes, in his Treatise on Coal Mines, states the waste of small coal at the pit's mouth to be one-fourth of the whole.

It cannot be deemed uninteresting to inquire what are the repositories of coal that can supply the metropolis and the southern counties, when no more can be obtained from the Tyne and the Wear. The only coal-fields of any extent on the eastern side of England between London and Durham, are those of Derbyshire and those in the west riding of Yorkshire. The Derbyshire coal-field is not of sufficient magnitude to supply, for any long period, more than is required for home consumption, and that of the adjacent counties. There are many valuable beds of coal in the western part of the west riding of Yorkshire which are yet unwrought; but the time is not very distant when they must be put in requisition, to supply the vast demand of that populous manufacturing county, which at present consumes nearly all the produce of its own coal mines. In the midland counties, Staffordshire possesses the nearest coal district to the metropolis, of any great extent; but such is the immense daily consumption of coal in the iron furnaces and founderies, that it is generally believed this will be the first of our own coal-fields that will be exhausted. The thirty-feet bed of coal in the Dudley coal-field is of limited extent; and in the present mode of working it, more than two-thirds of the coal is wasted and left in the mine.

If we look to Whitehaven or Lancashire, or to any of the minor coal-fields in the west of England, we can derive little hope of their being able to supply London and the southern counties with coal, after the import of coal fails from Northumberland and Durham. We may thus anticipate a period not very remote, when all the English mines of coal and ironstone will be exhausted: and were we disposed to indulge in gloomy forebodings, like the ingenious authoress of the "Last Man," we might draw a melancholy picture of our starving and declining population, and describe some manufacturing patriarch, like the late venerable Richard Reynolds, travelling to see the last expiring English furnace, before he emigrated to distant regions.*

Fortunately, however, we have in South Wales, adjoining the Bristol Channel, an almost exhaustless supply of coal and ironstone, which are yet nearly unwrought. It has been stated in the present chapter, that this coal-field extends over about twelve hundred square miles, and that there are twenty-three beds of workable coal, the total average thickness of which is ninety-five feet, and the quantity contained in each acre is 100,000 tons, or 65,000,000 tons per square mile. If from this we deduct one half for waste, and for the minor extent of the upper beds, we shall have a clear supply of coal, equal to 32,000,000 tons per square mile. Now if we admit, that the five million tons of coal from the Northumberland and Durham mines is equal to nearly one-third of the total consumption of coal in England, each square mile of the Welch coal-field would yield coal for two years' consumption; and as there are from one thousand to twelve hundred square miles in this coal-field, it would supply England with fuel for two thousand years, after all our English coal mines are worked out.

It is true, that a considerable part of the coal in South Wales is of an inferior quality, and is not at present burned for domestic use; but in proportion as coal becomes scarce, improved methods of burning it will assuredly be discovered, to prevent any sulphurous fumes from entering apartments, and also to economize the consumption of fuel in all our manufacturing processes.

N. B. These observations are taken from one of the author's geological lectures, which he has occasionally delivered in some of the principal mining districts in England: considering the great national importance of our coal mines, he trusts he shall be excused for inserting them in the present volume.

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* The late Richard Reynolds, Esq. of Bristol, so distinguished for his unbounded benevolence, was the original proprietor of the great iron-works in Colebrook Dale, Shropshire. Owing, I believe, partly to the exhaustion of the best workable beds of coal and ironstone, and partly to the superior advantages possessed by the iron-founders in South Wales, the works at Colebrook Dale were finally relinquished, a short time before the death of Mr. Reynolds. With a natural attachment to the scenes where he had passed his early years, and to the pursuits by which he had honorably acquired his great wealth, he travelled from Bristol into Shropshire, to be present when the last of his furnaces was extinguished, in a valley where they had been continually burning for more than half a century.

CHAPTER IX.

ON UNCONFORMABLE ROCKS OF PORPHYRY, TRAP AND BASALT, AND ON BASALTIC DYKES.

The different Positions of Conformable and Unconformable Massive Rocks described.—Opinions respecting the Formation of Unconformable Massive Rocks.—Varieties of Trap Rocks; their Passage by Gradation into each other and into Volcanic Rocks.—Porphyry, Porphyritic Trap, Greenstone, Sienite, Clinkstone, Basalt, Amygdaloid, Wacke, Pitchstone.—Passage of Porphyry and various Trap Rocks into each other, and into Sienite and Granite, at Christiania in Norway.—Passage of Basalt into scoriaceous Lava and Obsidian.—Mountains of Porphyritic Trap and Clinkstone with deep Craters, probably formed by depression.—High Stile, Cumberland.—Cader Idris, Wales.—Basaltic Dykes.—Columnar and Massive Basalt.—Interstratified Basalt.—Strata confusedly broken and enveloped in Basalt.—Organic Remains enveloped in Basalt.—Basalt of Scotland, Ireland, Auvergne, and Iceland.—On the formation of Basalt.—Experiments of Mr. Watt.—Theory of Werner.—On the relative age of Trap Rocks.

The rocks described in the preceding chapters, both of the primary, the transition, and the lower secondary class, generally cover each other in a conformable position; and where they occur together, their arrangement and order of succession may be represented as in Plate 3. fig. 1. where the granite *a* is covered by gneiss *b*, and this by mica-slate *c*. Next succeed the slate rocks *d d*, with imbedded or subordinate beds of flinty slate, or limestone. (1) Then follow beds (2) of conglomerate, separating the slate from the transition limestone and greywacke. (2. *d. d.*) And lastly, the lower secondary strata, comprising the great coal formation. This representation is, however, rather descriptive of a general tendency to such an arrangement, than of its universal occurrence. Frequently different parts of the series will be wanting in different situations. Thus in Cornwall the gneiss and the mica-slate are absent, except in two localities. At the Malvern Hills, transition limestone rises almost close to the rocks of granite: and the coal formation of St. Etienne in France is only separated from the granite, on which it reposes, by a thick bed of conglomerate, containing rounded stones of vast size, belonging to rocks of the primary class. Here all the intervening formations, *b. c. d.* and *e.* Plate 3. fig. 1. are wanting. Whether they were originally deposited, and have been subsequently removed, by the agency of some unknown cause, before the deposition of the coal strata, is an inquiry that can be answered only by conjectures and references to analogies: the subject will be hereafter adverted to. It is sufficient to our present purpose to remark, that where the different formations that are wanting in one place occur in another, they generally cover each other conformably in the order above described.

The upper secondary and the tertiary strata, that succeed the different classes of rocks which occur conformably, appear to have been deposited not only at a later period, but under different circumstances; for their position does not conform to that of the lower rocks, but they cover the outcrop or *basset* of the lower beds, as represented Plate 1. fig. 3; they are unconformable stratified rocks.

Before we proceed to describe the upper secondary strata, it will be necessary to bestow particular attention on a class of rocks, that has greatly perplexed the speculations of geologists: they are the unconformable rocks of porphyry, trap, and basalt, which form the subject of the present chapter. These rocks, though they sometimes occur imbedded in conformable rocks, more frequently cover them in an unconformable position, composing thick unstratified beds, and often mountain masses of vast size, that have not unfrequently a columnar structure. Their position is represented Plate 3. fig. 2. It is obvious that these unconformable rocks were formed and deposited, at a subsequent period to that in which the lower rocks were consolidated, and their beds had acquired their present inclined positions. As the unconformable massive or unstratified rocks, are many, if not all of them, allied to rocks whose igneous origin is now undisputed, we might have little difficulty in admitting that they had been poured over the surface of the conformable rocks in a state of fusion, like streams of lava from recent volcanos; with this difference, that they were not erupted from one opening or crater, but from fissures of great width and many miles or leagues in extent, and that they were formed under the ocean. I say we might have little difficulty in admitting this, particularly as such rents or fissures, filled with similar matter to that of the overlying unconformable masses, are often discovered in their vicinity: but there are other appearances which seem opposed to the igneous origin of these rocks. In the first place, similar rocks to the overlying formations, are often imbedded and intermixed with conformable rocks in a conformable position: and secondly, some overlying formations, appear to pass by gradation into rocks of the primary class. Now if we admit the unconformable masses to be of igneous origin, we can scarcely refuse the same origin to the imbedded rocks; and thus we extend the domain of Pluto over a larger portion of the crust of the globe, than many geologists will allow. It must also be granted, that many of the imbedded rocks of porphyry and porphyritic trap, which alternate or are intermixed with slate rocks, cannot be supposed to have ever been erupted like lava; but they may have been softened by subterranean heat *in situ*, and have taken the porphyritic texture, and the columnar structure, during their slow refrigeration. If we sufficiently keep in view that the crust of the globe with which we are acquainted, does not exceed, in comparative thickness, that of a wafer to an artificial globe three feet in diameter; and that a very large portion of the globe is now or has in ancient times been rent and pierced through by active volcanos, and that these volcanos are not the seat of subterranean fire, but merely its chimneys, we shall have no difficulty in admitting, that extensive parts of the crust of the globe may have been softened by internal heat, and the more fusible beds partly crystallized *in situ*, under the pressure of ocean.

Trap rocks sometimes occur between thick beds of marine limestone; but in such instances we may without much difficulty admit that these trap rocks have been formed by submarine volcanos, which have poured beds of lava over the limestone; another bed of limestone may have been subsequently formed over the lava, and this limestone may also have been covered by the lava of a later eruption. In this manner the alternation of beds of basalt, or basaltic amygdaloid with limestone in Derbyshire, may admit of a probable explanation.

With respect to the overlying formations which pass by gradation into primary rocks, as some porphyrics allied to volcanic rocks pass into granite,—this fact, so far from proving that the porphyry was not of igneous origin, would tend to confirm the hypothesis which attributes an igneous formation to granite itself.* It is granted by the best observers, that a regular gradation may be traced between granite and the more ancient volcanic rocks, and that there is likewise a gradation between the products of ancient and recent volcanos. Of the former we shall cite a well attested instance; but before proceeding, it will be proper to give a more ample description of trap rocks than has yet been done. It has already been stated, that rocks composed of felspar and hornblende, received the generic name of Trap rocks, (a name derived from the Swedish word *trappa* a stair,) because these rocks frequently divide into regular forms resembling the steps of stairs. Besides the intermixture of felspar and hornblende, there is also a frequent intermixture of felspar with augite, to which the name of trap rock is given; indeed, hornblende and augite resemble each other so much in chemical composition, and when uncrystallized, in external character also, that they have till recently been confounded together, and they often occur together in the same rock. These compounds of felspar and hornblende, and felspar and augite, form the different rocks called greenstone, sienitic greenstone, basalt, clinkstone, pitchstone, wacke, and amygdaloid; and also trap, porphyry, and pitchstone-porphyry. All these rocks may be regarded as different modes and combinations of felspar with hornblende or augite, differing chiefly in their internal structure.

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* However highly and justly distinguished many of the natural philosophers in France may be, it cannot be denied that they adhere more closely to theories once formed, and have a greater dread of thinking for themselves, than the philosophers of other countries. In confirmation of this, I shall translate an extract from M. Bonnard's *Aperçu Geognostique des Terrains*. It is truly amusing to see the alarm which he evinces, lest he should be compelled by stubborn facts to relinquish his cherished theories.—" Another species of difficulty should prevent every prudent man *(esprit sage)* from attempting to explain the formation of these rocks of trachyte by any hypothesis founded on volcanic action; namely, the alarming extent of the consequences which may follow such an explication, relative to other rock formations, hitherto regarded as having a very different origin." With great respect for M. Bonnard, I would say, Let every *esprit sage* yield to the evidence which Nature presents, and leave consequences and theories to take care of themselves.

When hornblende and felspar have a granitic structure, they form what is generally called greenstone, and if the felspar be red, sienitic greenstone. When hornblende and felspar, or augite and felspar, are intimately combined and finely granular, they form basalt. The French geologists make a distinction between the basalt in which augite prevails, and that which is composed of felspar and hornblende; but it is admitted that where the structure is finely granular, or nearly compact, it is difficult, if not impossible, to distinguish them.

Basalt has a greenish or brownish black colour, is difficult to break, and possesses a considerable degree of hardness; it will however yield to the point of a knife. On examination with a lens, even the more compact varieties of basalt are seen to be composed of minute crystalline grains; it frequently contains yellowish grains of a mineral called olivine; it contains also grains of iron-sand, and a considerable portion of the black oxide of iron. Basalt is fusible into a black glass, and is magnetic. The iron which it contains, passes into a further state of oxygenation when exposed to the air: hence basaltic rocks are generally covered with a reddish brown incrustation. Very black basalts are chiefly composed of augite.

Soft earthy basalt intermixed with green earth forms the rock called *wacke*. When basalt or wacke contain rounded cavities, filled with zeolites, chalcedony, or calcareous spar, they form amygdaloid.* When the felspar greatly prevails, and the texture becomes nearly compact, basalt passes into the rock called phonolite or clinkstone, from its yielding a metallic sound when struck: the prevailing colour is gray and greenish gray; it is fusible. Clinkstone when it has a more earthy texture, passes into the rock called by English geologists Claystone. Clinkstone often contains imbedded crystals of felspar, and then becomes a trap porphyry, which varies in colour according to the prevailing ingredients of its base. Between felspar porphyry and trap porphyry there is an almost imperceptible transition; in the former, the base or paste is felspar, nearly pure. Some felspar porphyries pass gradually into granite, by an intermixture with quartz and mica. Pitchstone has a blackish green, or a nearly black colour; it is a semivitreous substance, having the lustre and appearance of pitch; it is composed of the same constituent parts as basalt, and approaches nearly to the black volcanic glass called obsidian, which is a lava suddenly refrigerated and perfectly vitrified. Pitchstone and obsidian are sometimes porphyritic. Hence we have on the one hand a series of rocks, (varying only in the increase of felspar, and state of induration,) from granular basalt to clinkstone and claystone, from clinkstone to trap porphyry, from trap porphyry to trachyte and felspar porphyry, and from felspar porphyry, with the further admixture of mica and quartz, to granitic porphyry and granite. On the other hand, from granitic greenstone there is a transition to sienite, and from sienite to true granite. Again: in the volcanic districts of Auvergne, we see scoriaceous lava become more compact, and at length pass into well characterized black basalt, with the columnar structure. In other situations, currents of lava form obsidian or volcanic glass; and between basalt, phonolite, and pitchstone, there is an almost imperceptible gradation.

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* The names Porphyry and Amygdaloid rather represent modes than substances, and convey no precise ideas unless the nature of the base be specified.

Thus it may be seen that the whole family of trap rocks have on the one hand a close alliance with volcanic rocks; and on the other, with the more ancient rocks of porphyry and granite.

The gradation of trap rock, having in some parts a volcanic character, into true granite, has been described by Messrs. Hausmann and Von Buch as distinctly observable, and well marked, in a mountain near Christiania in Norway. The lower rocks are gneiss; over this occurs dark slate; and in the slate are several beds of blackish limestone containing trilobites, and also orthoceratites several feet in length, with other marine organic remains. In some parts, a bed of gritstone or greywacke rests on the slate. The whole of these beds are covered by an enormous mass of porphyry, varying in thickness from one thousand six hundred to two thousand feet. The porphyry is of a smoke grey colour, but is reddish in some parts; it is compact, and moderately hard, and contains large crystals of white felspar, and crystals of quartz, epidote, hornblende, iron pyrites, and magnetic iron ore. In the lower part of the bed the porphyry becomes vesicular, and changes into an amygdaloidal basalt, containing crystals of augite. Near the sea, vast dykes of this porphyry, more than thirty yards in width, are seen cutting through the slate and beds of limestone. In another part of the country, at Holmestrand, the same mass of porphyry, covering beds of sandstone. is seen to pass in the lower part, by almost insensible gradations, into a hard fine-grained black basalt, containing brilliant crystals of augite: in the upper part of the bed, the porphyry passes into a sienite of singular beauty, containing crystals of zircon; and above this, the sienite passes into common granite. The dykes of porphyry cutting through the slate rocks indicate the mode of formation of this porphyry, in a manner not to be mistaken by those who are acquainted with the basaltic dykes in the northern parts of Great Britain. These dykes were doubtless the fissures through which this vast mass of porphyry had been poured out over the slate rocks, though Messrs. Hausmann and Von Buch describe them as veins descending from the porphyry. The reader may form a more distinct idea of the position of this porphyry and its relation to the subjacent rocks, which are intersected by dykes of the same porphyry, from Plate 3. fig. 2. *a.*

Had M. Von Buch seen this remarkable mass of porphyry at Christiania, after his visit to the basaltic districts in England, he would, I am persuaded, have at once recognized the agency of subterranean fire in its formation. I saw this eminent geologist soon after his return from Cumberland and Westmoreland; and if I recollect distinctly his opinion respecting the mountains of porphyritic trap and clinkstone intermixed with slate in these counties, it was, that they bore a striking resemblance to some of the most ancient volcanic mountains in Auvergne, and that, like them, they had been softened *in situ*, and elevated by subterranean heat. The operation of igneous agency in these mountains is much less evident than in the porphyry of Norway, if the description given of it be correct. The only porphyry occurring in uncomformable beds that I have seen in Cumberland or Westmoreland, covers part of a mountain of coarse slate on the right hand side of the road going from Kendal to the granite mountain of Shap. It forms a nearly horizontal bed composed of red felspar, which has an earthy texture, and contains crystals or grains of quartz; it is what the French would denominate a red trachyte. Considerable fragments of the same rock are scattered in the adjacent valleys, proving that at a former period, this porphyry was more extensively spread over that district. A red porphyritic felspar, nearly similar in composition and appearance, forms the top of the mountain called Red Pike above the Lake of Buttermere in Cumberland. Closely adjacent to Red Pike, and forming part of the same ridge, is the mountain called High Stile. Between the summits of these mountains, is a deep crater with a small lake or tarn at the bottom of it: the sides of this crater are very steep; it is partly surrounded by rude columns of clinkstone on one side; the porphyritic felspar of Red Pike forms the other side. The clinkstone has a smooth conchoidal fracture and a greenish gray colour; it contains small crystals of felspar, and is slightly translucent on the edges and very fusible; it is highly sonorous when struck with a hammer. The height of High Stile is two thousand one hundred feet above the level of the sea; the depth of the crater is about five hundred feet; the side nearest the Lake of Buttermere, by which alone it can be entered, is partly open. Situated as it is on the summit of a very narrow steep mountain range, that divides the valley of Buttermere from Ennerdale, no conceivable operation of water could have scooped out the crater, and the bed of the lake within it.

Though the rocks which surround this crater are closely allied to volcanic rocks, and have probably been subjected to the agency of fire, we cannot suppose the crater to have been formed like that of modern volcanos, by eruption of lava and scoriæ. It seems more reasonable to admit that the crater might owe its form to a partial sinking down of part of the summit of the mountain, when the rocks of which it is composed were softened by subterranean heat, and elevated: the basin of the Lake of Buttermere, at the foot of this mountain, may perhaps owe its original depression to the same cause. Many of the mountains in these districts are composed of porphyritic trap, passing into clinkstone. In a deep ravine of Swarthfell in Cumberland, opposite the seat of J. Marshall, Esq. M.P. the mountain which is here composed of clinkstone, presents the columnar structure on a magnificent scale; the columns are slightly bent and inclined.

Porphyry, from an intermixture with hornblende frequently passes into sienite; when this is the case, the latter rock generally forms the upper part of the mass. Porphyry and basalt, in enormous masses, often cover the primary mountains in the Andes. According to Humboldt, "they are arranged in regular columns, which strike the eye of the traveller like immense castles lifted into the sky." Some geologists describe four formations of porphyry, but this division is purely theoretical, as those who admit it, agree that the different formations of porphyry frequently pass into each other; and from the evident connection of porphyry and basaltic with igneous rocks, it naturally follows, that such transitions must take place. Porphyritic rocks may in general be regarded as more ancient than basaltic rocks, as porphyry most frequently occurs intermixed with, or covering transition rocks, and basalt is most commonly associated with the secondary strata, which it either cuts through in the form of dykes, or covers unconformably. Sometimes it appears to have broken through the strata confusedly, and to have enveloped large portions of other rocks. We shall proceed to describe these different modes of its occurrence and position, of which we have numerous striking examples in Great Britain and Ireland.

In describing the phenomena presented by any one of the trap rocks, we describe those peculiar to every member of the trap family. Were it allowed to express a geological fact in familiar terms, it might be said, that all the members of this family give indications of a fiery character, and of having been troublesome neighbours to the adjacent rocks, disturbing them, and even changing their nature, when they are closely associated. Beside occurring in overlying unconformable masses, all trap rocks, with porphyry, which may be placed at their head, are occasionally found intersecting other rocks like vertical walls. It has been before stated, that these vertical walls are called *dykes*,—the term dyke and wall being synonymous in North Britain. The substance which most commonly occurs in dykes is basalt; and as these basaltic dykes are well known, from their frequently intersecting coal strata, we shall now give a description of basaltic dykes, and their effects on the adjacent rocks or strata.

The thickness of dykes varies from a few inches to twenty or thirty feet or yards; in some instances they exceed three hundred feet. The extent to which they stretch across a country has seldom been explored beyond the mining districts, where a knowledge of them is important on account of the disturbances which they occasion in the strata.

The intersection of coal strata by dykes is represented Plate 4. fig. 2. and 3 c. c. and d. d. Dykes generally decline a little from a vertical position; and, as before stated, the depth to which they descend is unknown.

The strata are almost always thrown down on one side of a dyke, and elevated on the other; but the dislocation is not proportioned to its breadth. There is a fault extending from Whitley in Northumberland, to Greenside and Sandgate in Durham, which has thrown down the strata on the north side one hundred and eighty yards; this is a comparatively narrow fissure filled with clay. A great basaltic dyke in the same county, which is seventeen yards wide, has only produced a dislocation of twelve yards.

The whole series of strata which have been raised above the surface on one side of a fault, have sometimes entirely disappeared, and the ground on each side of it, is on the same level. See Plate 4. fig. 2, 3.

Trap dykes, and basalt dykes, are generally harder than the rocks that they intersect; and when the latter are partly decomposed, often remain, forming vast walls of stone, that rise above the surface of the ground. There are walls of this kind in the counties of Northumberland and Durham, running along the country several miles. Dykes also extend into the sea, and form reefs of rocks; and when they cross the beds of rivers, they form fords, and sometimes hold up the water and occasion cascades, of which there are numerous instances on the river Tees. In the interior of North America, basaltic walls were discovered by Messrs. Lewis and Clark, of great extent; the walls were composed of columns of basalt arranged horizontally, and were at first supposed to be artificial constructions. Where basaltic dykes are of considerable thickness, the hardness of the stone varies in different parts; sometimes the inner parts are harder, and sometimes softer, than the outer, the substance in the dyke being divided by seams or partings. This may be distinctly seen at Coaly Hill, near Newcastle-upon-Tyne, where a large basalt or whin dyke cuts through the coal strata, and rises to the surface. The stone being hard, is quarried for the roads along a line of several hundred yards, forming a deep trench sufficiently wide to admit a cart-road through the quarry, between the sides of the dyke.

The basalt of the dyke is intersected by fissures, and divided into variously shaped masses. In one part of the dyke it appears to graduate into an indurated ferruginous clay, which is in some places divided into minute well-defined pentagonal prisms. This dyke had charred the coal on each side of it, and rendered it soft and sooty. To use the language of the workman who was quarrying the stone when I visited the place, " it had burned the coal wherever it had touched it." The same dyke extends from the sea to the western side of the county of Northumberland; its termination in that direction is unknown.

The longest mineral dyke that has been traced in England may be called the Cleveland Basalt Dyke: it extends from the western side of Durham to Bewick in Yorkshire; it crosses the river Tees at this place, and proceeds in a waving line through the Cleveland Hills in the east riding of Yorkshire to the sea between Scarborough and Whitby. It rises to the surface, and is quarried, in many parts of its course, for stone to lay upon the roads. From Bewick-on-the-Tees, it may be traced in an easterly direction, near the villages of Stanton, Newby, Nunthorp, and Ayton. At Langbath ridge a quarry is worked in it; it passes south of the remarkable hill called Roseberry Toppin, near Stokesly, and from thence by Lansdale to Kildale; it may be seen on the surface nearly all the way in the above track. From Kildale it passes to Denbigh Dale end, and through the village of Egton-bridge, and hence over Leace ridge through Gothland, crossing the turnpike road from Whitby to Pickering near the seven mile stone, at a place called Sillow Cross on a high moor. I examined it at this place, where it is quarried for the roads, and is about ten yards wide. From hence it may be traced to Blea Hill near Harwood Dale, in a line towards the sea, near which it is covered with alluvial soil; but there can be no doubt that it extends into the German Ocean. It is a dark greyish brown basalt, which turns brown on exposure to the atmosphere; it is the principal material for mending the roads in the district called Cleveland. I am indebted to Mr. Bird of Whitby for an account of the situations where it may be seen on the surface. He has traced it through Yorkshire and Durham; in the latter county it cuts through the coal strata. According to Mr. Bird, it crosses the river Tees again, near Tees Force, and, expanding, forms the great mass of basalt on the western extremity of Durham, taking the columnar form in various parts, particularly at High Cup, a deep circular excavation on the side of Cross Fiell. The specimens of the stone shown me by Mr. Bird from this district, are more crystalline and less homogeneous than that in Cleveland, being that variety called green-stone, consisting of hornblende and felspar. The course of this dyke is marked in the Geological Map of England, Plate 5. By consulting the large maps of England, the course may be distinctly traced: drawing a line in the direction from Cockfield in the county of Durham to Bewick-on-the-Tees, and extending the line east and west, it will pass near all the places above mentioned.

The Cleveland dyke has been traced in a direct line more than seventy miles. A circumstance attending this and other extensive dykes, which has not, I believe, been hitherto regarded by geologists, completely invalidates the theory, that dykes were originally open fissures formed by the drying or shrinking in of the rocks. This dyke in its course intersects very different formations, viz. the transition or metalliferous limestone, the coal district, and the upper secondary strata of lias and oolite. The different organic remains in these formations, as well as their position, prove that they were consolidated at distant periods of time. Indeed the geologists who maintain that dykes were formed as before described, are ready to admit the distant eras of these formations. The transition, or metalliferous limestone, and the lower strata, must have been completely consolidated, long before the upper secondary strata were deposited, and the causes which might dispose the upper strata to sink in, cannot be supposed to act on the lower rocks. It is also to be remarked, that in the lower rocks, situated to the west, the breadth of this dyke is more than twenty yards; but at Sillow Cross, where I measured it, it is not more than ten yards: this dyke must therefore become wider as it descends. It must also have been filled with basalt at the time of its formation, otherwise it would have contained numerous fragments of the rocks which it intersects.

The effects of this basaltic dyke on the different rocks through which it passes, are truly remarkable. When it comes in contact with the lower or transition limestone, it is said to render it more crystalline, a fact the geological importance of which will be subsequently adverted to. Where it crosses the coal strata, and comes in contact with the seams of coal, the substance of the oal is for several feet converted into soot. At a greater distance om the basalt, the coal is reduced to a coke or cinder, which urns without smoke, and with a clear and durable heat. At the stance of fifty feet from the dyke, the coal is found in its natu-l unaltered state. It is particularly remarkable that the roof mediately over the coal is lined with bright crystals of sulphur. some situations in the same county, the shale in contiguity ith basaltic dykes, is converted into flinty slate or jasper, and e sandstone is changed to a brick colour. There is another markable basaltic dyke in the same district, which crosses the estern extremity of Durham from Allenheads to Burtreeford on e river Tees, hence called the Burtreeford Dyke. It throws own the strata on the western side of it, one hundred and sixty ards.

Dykes being generally impervious to water, they obstruct its assage along the porous strata, and occasion it to rise: hence it equently happens that numerous springs make their appearance long the course of a dyke, by which it may be detected, when ere is no other indication of it visible on the surface.

Basaltic dykes intersect both primary and secondary rocks, t they every where present indications of their action on the jacent rocks. At Nigg, near Aberdeen, I examined a basaltic yke on the coast, which intersects a rock composed of gneiss; e dyke is about thirty feet in width. Where the basalt is in ntact with the gneiss, it becomes nearly compact, and ap-roaches to the character of hornstone; and the gneiss has a red d burnt appearance, approaching in its nature to porphyry. t is probable that the action of the basalt on the sides of the neiss rock, had softened it and rendered it more liable to disin-egrate than the other parts, for the sea has here made an inden-tion inland, forming a deep narrow ravine or bay, with a lofty all of basalt running through it. The wall of basalt completely ivides the bay, and the sea enters into both parts. It has been efore observed, that when basaltic dykes extend into the sea, ey form reefs of rocks, and small islands. These basaltic walls, hether rising above the surface of the country, or extending into the sea, serve to mark the destruction of the land; for we are certain, that these walls of mineral matter were at one period supported on each side by rocks or strata, which they have intersected, but which are now worn away. The Cleveland basalt dyke, it has been stated, cuts through the transition limestone, the coal strata, and the upper secondary strata, comprising a part of the oolite formation. On the northern coast of Ireland, Messrs. Buckland and Conybeare discovered a considerable basaltic dyke, passing through the chalk rocks. In the immediate contiguity of basalt, the chalk on each side of the dyke was rendered highly indurated and crystalline, this effect decreasing as the distance from the dyke increased.

The constant occurrence of dykes in basaltic districts gives a high degree of probability to the opinion, that overlying unconformable trap rocks have been erupted in a melted state like lava, and poured over the surface of the ground. Where extensive beds of basalt occur in low situations, there can be little difficulty in admitting this mode of formation; but the frequent occurrence of beds of basalt, forming isolated caps on distant mountains, was for a long time considered as opposing completely the hypothesis of the igneous origin of basaltic rocks; a more attentive examination of basaltic districts has however established the fact, that these isolated caps of basalt, are parts of continuous beds which have in remote ages been excavated by valleys, in the same manner as the beds of other rocks which frequently form isolated caps on detached mountains. The cap of gritstone on Whin Hill, near Castleton, see Plate 4, affords an illustration of this; and nothing is more common than to see the same bed of limestone, forming the uppermost stratum or cap of the mountains on each side of a valley.

The occurrence of thick beds of basalt, divided into regular pentagonal or hexagonal columns, and disposed in ranges of vast extent and height, could not fail to arrest the attention of the most careless observer, and give rise to speculations respecting their origin and formation. Basaltic columns are frequently seen in countries that are the seat of volcanic fires, but they occur also in countries very remote from any known volcanos; and the opinions of geologists were hence long divided on the subject of basaltic rocks, some ascribing to them an aqueous, and others an igneous origin.—The theories respecting their formation will be subsequently adverted to.

Few countries in the world present more magnificent basaltic columnar ranges than the north part of Ireland and some of the Hebrides: probably these are connected under the ocean, and have had the same origin.

The Giant's Causeway constitutes a small part of a vast basaltic range, along the north coast of Ireland, in the county of Antrim. The promontory of Fairhead and Borge, in the same range are situated eight miles from each other: these capes consist of various ranges of pillars and horizontal strata which rise from the sea to the height of five hundred feet; from their abruptness they are very conspicuous, and form a pile of natural architecture, in which the regularity and symmetry of art, are united with the wild grandeur and magnificence of nature. Many of the columns in the ranges at Fairhead are one hundred and fifty feet in height, and five feet in breadth. At the base along the shore is a wild waste of rocky fragments, which have fallen from the cliffs. Immense masses that have withstood the force of the shock lie in groups, resembling the ruins of enormous castles. At the Giant's Causeway the columns rarely exceed one foot in breadth, and thirty feet in height: they are sharply defined, and the columns are divided into smaller blocks, or prisms of one foot or more in length, which fit neatly into each other, like a ball and socket. The basalt is close grained, but the upper joint is cellular. The columns are most frequently formed with five or six sides; but some have seven or eight, and others not more than three. Beds of basalt that are not columnar, in some situations lie over, and also under the columns. The basalt in these beds is cellular, and contains zeolites in its cavities. The columns at Fairhead are not articulated like those at the Giant's Causeway; but the blocks, which are of great length in each column, lie flat on each other. Basalt appears to extend on the coast and inland about forty miles in length, and twenty in breadth.

A full and perspicuous account of the geology of this part of Ireland, is given by Messrs. Buckland and Conybeare in the 4th volume of the Geological Transactions. It appears that this basaltic range rests upon lias limestone containing marine shells and ammonites; the basalt also enters chalk-rocks, which are much broken by it, and in one part a considerable mass of chalk is completely enveloped in basalt. The effect of a basaltic dyke in crystallizing the chalk on each side of it, has already been mentioned. Former observers, unacquainted with the nature of the rock on which the basaltic ranges of the Giant's Causeway rest, have mistaken it for basalt; it is a dark coloured highly indurated limestone, and as it contains shells and other organic remains, these remains were erroneously supposed to prove the marine origin of basalt.

The basaltic columns of the Island of Staffa are too well known to require a description; but, according to Dr. MacCulloch, the columns which form the lofty promontory called the Scuir of Egg, another of the Hebrides, exceed in grandeur and in picturesque effect those of Staffa: they are formed of black pitchstone, containing crystals of glassy felspar. "The promontory rests on a bed of compact gray limestone, approaching to a stone marle. This bed, which is three or four feet thick, rests on a still lower bed of hard reddish stone. Masses of bituminized wood, penetrated with carbonate of lime, are found in the marle stratum not at all flattened. Portions of trunks of trees, retaining their original shape, but petrified (silicified,) are found in the same stratum; the rifts are filled with chalcedony, approaching in aspect to semi-opal. The columns on this island are both perpendicular and inclined, and some of them are bent or curved."

In various parts of Scotland and the Hebrides, the tendency to a columnar arrangement in the basaltic rocks may be distinctly seen: it is obscurely developed in the basalt of Arthur's Seat near Edinburgh. The basalt of this hill appears identical with some of the volcanic mountains I examined in Auvergne, particularly near the summit of Montadoux, a mountain near Clermont.

In England the columnar structure of some of the basaltic and trap rocks is observable in the northern counties, particularly on the banks of the river Tees, and at Swarthfell near Ulswater. In some of the basaltic hills near Dudley, the columnar structure is developed, but the columns are not separated and well defined. Prismatic blocks of sienite are scattered over a hill of sienite called Markfield Knowl, at Charnwood Forest in Leicestershire.

Columns of porphyritic trap or greenstone occur in groups, on the northern side of Cader Idris, a mountain in Merionethshire. One of these columnar groups is represented Plate 6. fig 1. the outline of the columns was taken with a camera lucida by Henry Strutt, Esq. of Derby, and cannot fail to be correct; the figure is introduced, to show the relative magnitude of the columns. Rocks of trap and basalt, both in solid beds and also arranged in columns like those of Staffa, were observed by Sir G. Mackenzie on the coast of Iceland, and also in the interior; the lower parts of the beds and columns contained scoriæ and slags, and empty cavities. A successive range of beds of basalt was also observed alternating with beds of tufa, the lower parts of which presented the same appearance of the action of fire.

From the situation of these rocks, and from the existence of submarine volcanos near Iceland, Sir G. Mackenzie conceives that these beds of basalt were formed under the sea by the ejection of lava, which flowing over the moist submarine ground, would confine a portion of water beneath the melted mass: this water would be converted into elastic vapour, or steam, which would endeavour to expand; but where the superincumbent pressure of the ocean, or the tenacity of the lava, prevented its escape, it would be compressed, and form cavities, or air bubbles, at the bottom of the melted mass. In other instances, where the fluidity of the lava permitted the steam from below to escape through it, the mass would be compact, and form solid basalt, or greenstone. It might sometimes happen that water would be inclosed in the cavities of the mass, which is found to be the case in some basaltic rocks.

Thus according to the different circumstances of pressure from the depth of the ocean, and from the tenacity of the melted mass he supposes that porous and vesicular lava, or compact basalt, might be formed from the same eruption; or the mass might be porous below and compact above.

As Iceland is at present the seat of active volcanos, and as submarine volcanos are forming rocks near the shores of that island, Sir George Mackenzie's explanation of the causes which have produced the various appearances in the basaltic ranges of that island, seems highly probable. In Sicily the connection of basaltic with volcanic rocks has been clearly established by Ferrara, professor of Natural Philosophy at Catania.

In the vicinity of Clermont Ferrand in Auvergne, a thick bed of basalt has once covered an extensive tract of country; it rests upon a bed of volcanic tufa, and the latter frequently covers beds of fresh water limestone. This bed of basalt and the subjacent tufa and limestone, have evidently been furrowed and excavated by the same causes which have excavated valleys in other parts of the world; hence the basalt occurs forming isolated caps on many of the mountains. In some parts a gradation may be traced in the same bed from a compact basalt, similar to that of Arthur's Seat near Edinburgh, to porous basalt approaching more or less to the state of scoriaceous lava. But the basalt of this country belongs evidently to volcanic products, and will be described in the chapter on volcanos. It may be proper to remark, that as the basalt of Auvergne covers beds of fresh water limestone, which belong to the tertiary strata, its age is evidently posterior to that formation of limestone, which is regarded as the most recent.

Basalt sometimes presents a globular structure, globes of hard basalt being imbedded in a mass of basalt of a softer kind.

Wacke or earthy basalt has frequently a greenish or reddish brown colour; it often contains cavities which are generally filled with nodules of agate, or with zeolite or calcareous spar. The agates are composed of concentric layers, and have apparently been formed by siliceous infiltration depositing successive coats within each other, until the cavity is filled up. Basaltic rocks of this kind are called amygdaloids. The Hill of Kinoul, in the vicinity of Perth, is formed of basaltic amygdaloid, containing agate nodules in great abundance, of various dimensions, and beautifully striped. At Woodford Bridge, in Gloucestershire, there is a low rock of amygdaloidal wacke, which is much intermixed with green earth, and has in some parts a saponaceous feel; the agates which it contains are decomposing, and the internal concentric layers are separated from each other, and present the appearance of edges of folded paper, with small interstices between each. I examined this singular rock in 1816; it was then quarried for stone to mend the roads. In some parts of the rocks I found masses of corallite of considerable size enveloped in the basaltic amygdaloid. I found also in this rock well defined groups of prehnite, which was not then known to be an English mineral: it has since been discovered in the basalt of Staffordshire.

The occurrence of organic remains enveloped in basalt, of which there are various instances, may admit of an easy explanation, if we allow that basalt has once flowed like lava at the bottom of the ocean. Modern lavas often envelop bones and other substances that they meet with in their course.

Imbedded interstratified basalt or trap is sometimes found alternating with rocks of undoubted marine origin. In Derbyshire there are three beds of basaltic amygdaloid separated by thick beds of transition limestone. Mr. Westgarth Forster has described an enormous bed of basalt in Northumberland and Durham, called the great Whinstone sill, placed between regular strata of limestone and gritstone: this bed varies in thickness from twelve to sixty yards. Other instances might be cited of basaltic beds interposed between regular strata, but frequently the strata are broken and disturbed in the vicinity of the basaltic beds. At Salisbury Craggs near Edinburgh, there is an instance of a bed of sandstone apparently broken by its contiguity to trap; the sandstone, near its contact with the trap, is converted into a substance approaching to jasper. A very interesting account is given by Dr. MacCulloch of the partial interposition of beds of trap, in strata of sandstone, on the coast of Scotland, where the trap may sometimes be seen forming apparently regular beds between strata of sandstone, and suddenly rising through part of the upper strata, and forming other beds above. A general idea of this mode of interposition is represented Plate 3. fig. 2. where the strata under a bed of columnar basalt, are intersected vertically by a dyke, and laterally by beds of basalt of limited extent. In such cases we may trace the effect of a disturbing force, which intruded the basalt in a melted or softened state between strata of sandstone.

The beds of Derbyshire toadstone, and the great Whinstone sill in Northumberland and Durham, may have been formed by repeated eruptions of lava over the bed of the ocean; or, what is less probable, they may have been intruded long after the formation of the strata, with which they are at present associated.

It has been generally believed, that the veins of lead ore in Derbyshire, which pass through the beds of limestone, are entirely cut off by the toadstone; and if this could be proved, it would favour the opinion, that the beds of toadstone had been intruded between the beds of limestone, after the formation of the metallic veins. In some instances, however, the veins of lead ore do pass into the toadstone, and are rich in ore. It is now even doubted whether all the veins do not pass through the beds of toadstone, though they may become very narrow or yield no ore when in the latter rock. The information which I could collect from the most intelligent miners, when I was last in that county, still leaves the question undecided.

Plate 4. fig. 5. represents the bed of limestone *b. b. b.* separated by beds of toadstone *c. c.* In this section the veins are represented as cut through by the toadstone: if this be really the fact, it will, as before stated, favour the opinion that they were intruded subsequent to the formation of the veins.

The interesting observations of Dr. Daubeny, in his Sketch of the Geology of Sicily, seem clearly to ascertain, that beds of amygdaloidal trap, alternating with beds of limestone, have, in that island at least, been formed by successive currents of lava flowing over the bed of the sea, at intervals of time so distant, as to allow the deposition or formation of a bed of limestone over each current of lava. A considerable district near Lentini, on the southern side of Mount Ætna, and also a part of the island near Cape Passero, are composed of alternating beds of lava, with tertiary limestone abounding with organic remains of madreporites, nummulites, cerithea, and the remarkable fossil called the Hippurite. Santa Venera, the loftiest mountain in the south of the island, is capped with cellular lava; beneath it is a bed of limestone with minute shells; at a lower level towards Lentini, there is a second bed of volcanic matter similar to the first; and two other similar alternations of beds of limestone and lava, occur still lower down. Dr. Daubeny says that the cellular and semi-vitreous aspect of many of the volcanic beds associated with the beds of limestone, precludes all doubt respecting the manner of their formation: the character of other portions presents strong analogies to rocks of the trap family; "they are compact, and have a stony fracture; they contain crystals of olivine, and the cavities are fillèd with calcareous spar or zeolites, like the amygdaloids of more ancient strata; and in some of the beds, a tendency to a columnar arrangement is discernible."

This account of Dr. Daubeny's affords additional proof of the close connection of ancient volcanic rocks with trap rocks,—may we not add, of their perfect identity: it is beside highly illustrative of the alternation of the beds of basaltic amygdaloid in Derbyshire, with beds of limestone. But in both instances, we must admit that the beds were formed under the ocean, before the present islands and continents had emerged from the watery abyss.

The disturbances and contortions of some of the lower beds of transition limestone, in the vicinity of trap rocks, were mentioned in Chap. VII. In such instances, though frequently no visible connection between the rocks of trap and limestone can be traced on the surface, there can be little doubt that such connection exists. The singularly bent limestone beds at Wren's Nest Hill near Dudley, are at a considerable distance from the nearest basaltic hill; but I observed in the town of Dudley, where a well was sinking, that the stone thrown out, was granular basalt intermixed with calcareous spar.

Some species of trap rocks, and particularly the softer kinds of basalt, decompose rapidly, and form productive soils and marls. I am inclined to believe, that some of the most fertile soils in England were formed by an intermixture with decomposed basaltic rocks. What has been called basaltic tufa, is a volcanic substance, and will be described among volcanic products. Some of the trap rocks, particularly the porphyritic traps, are metalliferous; but it is rarely the case with any of the British trap rocks, and it has before been stated, that the veins of lead ore in Derbyshire are either cut off by beds of basalt, or generally cease to yield ore when passing through basalt.

Having described the principal phenomena attending trap rocks, whether occurring in dykes, in unconformable masses, or interstratified with other rocks, it may be proper to mention certain experiments that have been made, to elucidate the formation of basaltic rocks. All trap rocks are fusible, and most of them form a blackish-green glass after melting: hence it was inferred, that trap rocks had never been in a state of fusion; for if they had, they would have been rendered vitreous. Sir James Hall, however, reflecting on the long period of refrigeration that vast masses of melted rock would necessarily require before they were cooled to the common temperature of the earth, was induced to make experiments on lava and basalt; from which it was ascertained, that if a small portion of liquid lava were suddenly cooled, it formed a black glass, as was well known to be the case with basalt, but if the process of cooling were slow, both melted lava and basalt became stone. When the glass which had been formed by sudden cooling was melted again, and suffered to cool very gradually, it lost its vitreous character, and was converted into a substance resembling basalt. Mr. Gregory Watt made some experiments on the fusion and refrigeration of basalt, in one of his father's furnaces, which throws much additional light on the formation of the globular and columnar structure of basaltic rocks. He fused seven hundred weight of the Dudley basalt called Rowley ragg, and kept it in the furnace several days after the fire was reduced. It melted into a dark-coloured glass with less heat than was necessary to melt the same quantity of pig-iron. In this glass, small globules were formed, which afterwards disappeared; and as the cooling proceeded, the mass was changed from a vitreous to a stony substance: other globes were again formed within the stony mass, which continued to enlarge until their sides touched and pressed against each other, by which pressure the globes formed polygonal prisms. If part of the mass were cooled before the globular structure was destroyed, these globes were harder than the surrounding stone, and broke in concentric layers. In this manner the balls of basalt and porphyry which fall out of decomposing rocks were probably formed; they derived their superior hardness from the crystalline arrangement of the particles when in a melted state. When these globes were enlarged by a continuation of the same process, they might press on each other, and form prisms. The upper prisms pressing by their weight upon the lower, might form concavities or sockets, into which they would sink, and remain jointed together or articulated. Such is frequently the structure of basaltic columns.

Another experiment, made by Sir James Hall, on the crystallization of common limestone by heat, and its conversion into marble, tends to elucidate the effects produced by basaltic rocks, on limestone and chalk before mentioned. Dr. Hutton had advanced the opinion, that beds of limestone were formed of the shells and exuviæ of marine animals, which had been melted by central fire, and crystallized. The first part of this theory respecting the entire formation of calcareous rocks from animal remains, it is not necessary to discuss at present: that a considerable portion of many limestone rocks were so formed, cannot be denied.

It was however objected to this theory, that the well-known action of fire on limestone rocks would expel the fixed air, and render them soft and pulverulent. To this objection it was replied, that as the action of central heat on beds of marine shells took place under the ocean, the pressure of the water would prevent the escape of the fixed air, and would probably render the calcareous earth more fusible. This answer was regarded as a mere hypothesis for some time, but Sir James Hall determined to try its validity by experiments. Having calculated the resistance which a column of water fifteen hundred feet, or any given depth, would present to the escape of fixed air, he inclosed a quantity of powdered chalk in a gun-barrel, and confined it in such a manner as to present an equal degree of resistance. He subjected the powdered chalk, thus confined for some time, to the action of a furnace; it was then drawn out and cooled, and was found converted into crystalline limestone or marble; and in one instance, where the chalk inclosed a shell, the shell had acquired a crystalline texture, without losing its form. Hence in situations where chalk or earthy limestone is found to have a crystalline texture, when in contiguity with trap rocks, we may with a high degree of probability infer, that the limestone had been fused by the trap.

A recapitulation of the facts and experiments which prove the igneous origin of trap rocks, would afford a mass of evidence which might convince the most sceptical inquirer: but such a recapitulation is needless, as in many situations undoubted currents of lava pass into trap rocks, and we have ocular demonstration of the fact.

The reason why geologists were so long opposed to the igneous origin of basaltic rocks, may partly be explained by the attachment to received theories, and partly by the reluctance to admit a condition of our planet, so remote from present experience. It was thought an ample claim on our credulity, when we were required to believe, that all the habitable parts of the globe had been for ages submerged in the ocean, without requiring the further belief, that countries now remote from active volcanos, had been repeatedly subject to the agency of subterranean fire.

Yet both these positions must be granted, if we will allow a legitimate induction from established facts.

The advocates of the aqueous origin of basaltic rocks, while they advanced theories which made claims upon our faith, equally unsupported by present experience, failed entirely in their attempts to explain the causes of existing phenomena in a satisfactory manner. The theory of Werner was for some time zealously supported, and particularly the least tenable part of it,—the formation of basaltic rocks by a second rising of the ocean, which deposited them on the summits of elevated mountains.—It may be proper to give a brief account of this part of the Wernerian system, before it entirely sinks into oblivion.

According to the theory of Werner, all the superficial parts of the globe were once in a state of aqueous solution, from which the materials were at first separated by chemical deposition in a crystalline state, and formed a thick mass of granite round the globe. Upon granite, the primary rocks were successively deposited, forming layers over each other like the coats of an onion. Over these again were laid the transition rocks: and next, the earthy stratified rocks. Each of these layers was supposed to encircle the globe, or to be an universal formation. While this process was going on, the waters were gradually retiring and became turbid: hence the materials which they deposited to form the upper strata, were more earthy than those of the primary rocks; they were also intermixt with fragments of the rock previously formed. According to this system, mountains and valleys were caused by the original inequality of the nucleus of the earth. So far the parts of Werner's theory are consistent; and we have a world ready made, in which every thing might be supposed to remain quiet; but—*non sic Fata sinunt;*—Neptune, ashamed of his late retreat, and indignant at his confinement in such narrow limits, calls the infernal deities to his assistance, and rising in his might, once more takes possession of the globe. He covers it with the depurgations of his turbid waves: but again he is compelled slowly and reluctantly to retire from the field, leaving behind him the basaltic rocks, the monuments of his triumph and his shame.—Such is in substance the theory of Werner respecting the origin of all the superincumbent rocks of basalt and trap. They are also, according to this theory, universal formations. It is scarcely possible for the human mind to invent a system more repugnant to existing facts. Were basaltic rocks deposited from a solution which covered the globe after the formation of secondary strata, as Werner supposes, every part of the dry land and every valley must have been incrusted or filled with basalt,—it would be the prevailing rock of every district. On the contrary, basalt exists only in particular situations, forming dykes, and overlying masses or beds of limited extent: nor do fragments of basalt occur in any quantity to warrant the belief that it was ever formed universally over the globe; and what is here said of basalt, applies equally to all unconformable rocks of porphyry, and the other trap rocks. Nothing but the obscure language in which the doctrine of Werner was advanced, could have prevented its absurdity from being instantly perceived and acknowledged.

With respect to the relative age of trap rocks, it is evident that if they are of igneous origin, they may have been formed at any period. We have certain indications that basaltic rocks were formed at different epochs; some of the basaltic dykes which cut through the coal strata in the northern counties, do not enter the magnesian limestone that covers the coal strata. Hence it is clear, that such basaltic dykes were formed before the magnesian limestone was deposited; while the Cleveland basalt dyke passes through many of the upper secondary strata, above the magnesian limestone, and is therefore of posterior formation to that rock.

OBSERVATIONS.

The unconformable porphyritic and basaltic rocks, which are the subject of this chapter, cannot be classed according to their relative ages, as they occur with all the other classes of rock. From this circumstance, the author has, on reconsideration, been induced to deviate somewhat from the arrangement proposed in Chapter I., and to place the unconformable massive rocks after the primary, transition, and lower secondary rocks, which cover each other conformably. Between the deposition of the lower secondary and the upper secondary rocks, there appears to have been a considerable pause or interval, during which the beds of the lower rocks were elevated, before the upper were deposited upon them unconformably. Hence it was thought, that the description of the unconformable massive rocks might properly be placed between that of the lower, and the upper secondary: and should any of my readers be disposed to deem the position of this chapter unconformable with the order first proposed, let them recollect, that I had unconformable subjects to treat of. In the brief sketch of the different classes of rocks given in the first chapter, it was not thought desirable to perplex the learner, or disturb the regular succession of the different classes of rock, by introducing those which occur among them all unconformably. By this deviation from the original arrangement, it will be necessary to make the upper secondary strata a class distinct from the lower secondary; and the difference between them is so well marked and definite, that they may properly be regarded as forming two classes. The alteration here mentioned, amounts however to nothing more than a mere difference in the collocation of the classes.

CHAPTER X.

A RETROSPECTIVE VIEW OF CERTAIN GEOLOGICAL FACTS AND INFERENCES STATED IN THE PRECEDING CHAPTER.

BEFORE we proceed to the Upper Secondary Rocks, it may be useful to review some of the leading facts stated in the preceding chapters, and to notice certain inquiries, which may naturally present themselves to the mind of the geological student. It appears from an examination of the crust of the globe, wherever it has been scientifically explored, that there is an order of succession or superposition in the rocks of every country, which may often be traced over a considerable extent; and that in countries very remote from each other, an approximation to the same order is observable, except in one class of rocks which are obtruded irregularly, and cover other rocks without any determinate order of succession, as described in the last chapter. It not unfrequently happens, that in a series of rocks which occur in two distant districts, some members of the series may be wanting in one, which we find in the other; but still the order of those rocks which remain will be the same in both. It is easy to conceive that the cause or causes, whatever they may be, which have formed certain rocks, have been limited in the extent of their action, as we know to be frequently the case on a smaller scale, where a stratum of sandstone, &c. after preserving its regular thickness for several miles, becomes gradually narrower, till at length, in the language of the miner, it *wedges out*, and the stratum above and beneath comes in immediate contact. In other instances, the rock which is interposed between two well known and identical rocks in distant districts, is not the same in both: this may be frequently observed among the upper secondary strata, which will next be described. In such cases, the different rocks that occur in the same geological position have been called equivalents of each other. An instance mentioned in a preceding chapter, may serve to explain what is meant by a geological equivalent. In the beds of transition limestone at Llanymynal, which are very regularly stratified, one stratum of the best limestone suddenly terminates, and its place is supplied by a bed of marle of equal thickness; in the same manner as we might suppose part of a course of bricks to be taken out of a wall, and its place filled up with clay; the clay would be the equivalent of the course of bricks.

In many of the lower conformable rocks, there is a frequent tendency to reproduction in the upper parts of the series: thus, though the regular order of succession may be granite, gneiss, mica-slate, and slate, (the clay-slate of Werner,) we often find beds of granite among gneiss and mica-slate, and sometimes even in slate. When, however, we consider, that the chemical composition of all .these rocks is very nearly the same; that silex forms on the average three-fourths of their constituent parts, and alumine about one-sixth or one-eighth,—the proportions of the remaining parts cannot greatly affect the condition of the mass; and it is to the circumstances, (whatever they may be,) which have occasioned a more or less rapid consolidation of the parts, that we ought, probably, to attribute the formation of granite in one part of a mountain, and of gneiss, mica-slate, or slate in another, and the reappearance of granite above the latter rocks. An inquiry naturally suggests itself, on observing that the order of succession in rocks is not invariably the same in distant countries? Are the similar rock formations in distant parts of the world cotemporaneous? or were rocks of different classes forming at the same period? Is the granite of England for instance more or less ancient than the granite of the Alps? or, are the secondary strata of one country, as old as the primitive rocks of another.

Were it not for the organic remains in different rocks, we could not (as Cuvier has well observed,) be certain that all rock formations were not cotemporaneous. With respect to those rocks which contain no organic remains, and under which there are no other beds containing organic remains, we must grant that they may be cotemporaneous, or they may have been formed at different and distant epochs. The beds of granite which are nearly vertical in mountain ranges, must have acquired a considerable degree of solidity, before the period when the beds were raised: but if we date their age from the epoch of their elevation, we shall be obliged to admit the different ages of granite mountains, and that the granite of Charnwood Forest, is more ancient than that of the Alps. Of this we have as direct proof as we could possibly require. In the Alps, the beds of the upper secondary strata, analogous to our magnesian limestone, lias, and oolite, are raised into nearly a vertical position conformable to that of the beds of granite, and they must all have been elevated at the same time.—See Plate 2. fig. 2. where the relative situation of the beds of upper secondary limestone is represented, *a. a.*

At Charnwood Forest in Leicestershire, very highly inclined beds of granitic and slate rocks are covered with horizontal beds of the upper secondary strata, analogous to those in the Alps. See Plate 2. fig. 4. *a. a.* Now it is evident that the granitic and slate rocks were raised before the horizontal strata were deposited upon them. Hence we attain the knowledge of an interesting fact in the natural history of our island;—its low ranges of primitive or transition hills are more ancient than the majestic mountains of Switzerland and Savoy: nor can this conclusion be invalidated, unless we admit what would be contrary to analogy, that secondary strata, possessing the same geological relations and the same organic remains, were formed at different epochs. I have cited the Charnwood Forest hills, because there the proof is more direct and palpable than at the Malvern Hills or elsewhere; for the horizontal upper secondary strata, may be seen resting immediately on highly inclined beds of granitic and schistose rocks.

The horizontal beds resting on the Charnwood Forest granite and slate, are composed of sandstone, a part of the red marle and sandstone formation; and at a little distance the sandstone is covered by strata of lias limestone, *b. b.* which determine its relative age. In some parts the sandstone strata also cover the coal strata, and the latter rise very abruptly as they approach the granite in the north. At the Vosges mountains in France, the same red marle and sandstone, associated with lias, covers the granite and coal strata unconformably.

When M. D'Aubuisson published his *Traité de Geognosie*, in 1819, he asserted, that the beds of granite in the Alps were raised into their present vertical or highly inclined position soon after their original formation. I visited the Alps in the two following years, and the appearances presented by the secondary strata compelled me to draw a very different inference respecting the period when the beds of granite were elevated, which I stated in the second volume of my Travels, published in 1823.

"One important fact may be deduced from these elevated beds of pudding-stone, sandstone, and other strata, comparatively modern, ranging conformably with beds of granite and gneiss; namely, That the beds of granite did not acquire their elevated position till after the formation of the secondary strata. In England, the elevation of the beds of granite was anterior to the deposition of the upper strata, consisting of magnesian limestone, lias limestone, oolite, chalk, and the intervening sandstones; for all these strata lie nearly flat over the edges of the inclined under strata. On the contrary, in Savoy, strata of similar formations occur nearly vertical, and frequently conformable to the range and dip of the granitic formations. These facts would prove, that the causes which have elevated granite, have acted at different epochs on various parts of the globe, unless we are prepared to admit that similar calcareous formations, containing similar organic remains, were not cotemporaneous in different countries."

In the latter part of the same volume I further stated, that as some of the strata on the Diableret mountains in the Vallais contain, at the height of seven thousand feet, fossils similar to those of the tertiary strata in the Paris Basin, it was more reasonable to believe that they had been raised since their deposition, than that freshwater formations had covered any part of the earth at such a vast elevation; and hence we may infer, that the epoch when the granite of the Alps was raised, is comparatively recent.*

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* Since the author published his opinion, in 1823, respecting the recent elevation of the Alps, founded on an attentive examination of the structure of the Pennine and Bernese Alps; M. Von Buch, M. L. Elie de Beaumont, and M. Andre de Luc. of Geneva, have advanced similar opinions, and stated that the elevation of those mountains took place after the formation of the tertiary strata.

It may be said that geologists formerly admitted the different ages of granite; by this they generally meant to apply the term Newer Granite, to the beds of granite which occur in gneiss or mica slate, which being above the great formations of granite, may perhaps be regarded as more recent. Some geologists have indeed attempted to discover a difference in the age of different granites which they regard as primary; but they have not clearly informed us whether they admit the existence of an older primitive granite, under the newer. The attempts which have been made to distinguish the newer and older primitive granites by their mineral characters appear so nugatory, that I feel much surprised that M. Humboldt, a geologist to whom science owes so much, should have lent the sanction of his authority to such a useless labour. In every country, granite, under whatever mode it may present itself, whether large or small grained, or slaty, if it be the lowest rock that can be observed, and if it be covered by either gneiss, mica-slate, or slate, may be regarded as the primitive foundation rock of that country, if there be any use in preserving the term: its relative age, compared with that of other countries, can be determined only by the position of the rocks that rest upon it.

With respect to the identity of age, or what is pedantically named the synchronism of rock formations in distant countries, there can be little hesitation in admitting it, where the association with other rock formations is similar in both countries, and particularly where a similarity of mineral character is observable. It will not be denied that the chalk and oolite in Yorkshire were cotemporaneous with certain parts of the chalk and oolite formations in the southern and western counties. In the same manner, we may admit that the chalk, and oolite, and lias, on the opposite side of the Channel, in France, are cotemporaneous with similar formations in England, with which they preserve an identity of mineralogical and zoological characters. Having once traced these formations to the North of France, we may admit their identity with similar formations, preserving the same identity of character through many of the inland departments of France.

and to the Salins at the foot of the Jura range. Over so large an extent of country we may expect to find, as we do in distant districts in England, that certain parts of a series which occur in a certain formation in one place, are wanting in another. In France, some beds occur, in the lias for instance, which have not hitherto been found in Great Britain: but making allowance for such partial variations, we cannot hesitate to admit the identity of the formations in both countries, and also their identity of age. When we enter the Jura, or the great calcareous ranges of the Alps, the enormous thickness of the beds, which are frequently inaccessible, and the indurated and subcrystalline texture which they often assume, present considerable difficulties, when we attempt to identify them with well known formations. Much confusion and contrariety may be observed in the classification of these rocks by different geologists: but this has arisen partly from the observers not being thoroughly acquainted with the formations with which they were to make the comparison, and partly from the vague and contradictory use of the terms Alpine limestone (*calcaire Alpin*,) and Jura limestone (*calcaire de Jura.*) There is, however, in some parts of these mountains, both an identity of mineral, and of zoological characters, with some of the formations in the upper secondary strata in England. A thick bed of blue lias filled with the *Gryphæa arcuata*, in the mountains on the lake of Annecy, and fragments of oolite, like that of Gloucestershire, from the top of Mont Grenier, near Chamberry, left me no doubt of the identity of the formations of England, France, and Savoy; and no reason can be assigned, which might lead us to infer that the similar formations in each country were not cotemporaneous. With respect to very remote countries, or the countries in opposite hemispheres, we have as yet few data to determine whether there be an identity of fossil remains, which can identify formations that may appear analogous, when they occur in very different latitudes, and under very different degrees of temperature.

There is another circumstance, independent of climate or remote distance, that may have occasioned a change in the genera, and even in the orders and classes of animals, whose remains are found in similar strata. The ocean may have been much deeper in one part, than in another not very remote, and the deepest bed of the ocean might support genera of pelagian animals;* while a more shallow adjacent part, might be tenanted by different genera, and even different orders and classes of animals, whose organization fitted them for moving nearer the surface of the water. The transition strata were probably formed under a great depth of the sea: and the animals that possessed the power of locomotion in an eminent degree, whose remains are found in those strata, are not numerous; these are the chambered univalve Moluscæ. Their shells are mostly cylindrical or conical, divided into different cells, with a tube or siphunculus passing through each cell, by which they were enabled to exhaust the water, and rise to the surface from immense depths. The shells of these animals did not form an outer covering, but were partly enveloped in their bodies; they had heads surrounded by feelers and large eyes, their beaks were like those of the parrot.† The feelers which surrounded their heads, served them for seizing their prey, and for swimming and walking at the bottom of the sea; they swam with their heads behind them, and when they walked their heads were downward. There are only two known genera of chambered animals of this class inhabiting the present seas; the Nautilus, and the Spirula,—their shells are spiral; the greatest number of chambered fossil shells found in the upper secondary strata are also spiral, and are well known, as Ammonites and Nautilites. It is probable that the animals that had straight chambered shells, possessed greater facility of rising to the surface than the spiral ones, and accordingly we find them chiefly in the oldest and lowest formations. The animals of this class having heads and various senses, seem to rank high in the scale of sentient organic beings; but they are not numerous till we rise into the upper secondary strata above the coal formation. Very few spiral unchambered shells occur in the transition rocks; for these animals crawl on their bellies like the snail, and do not seem fitted to live in deep water, unless like the Helix Janthina, which nearly resembles the snail and lives in the Southern Ocean, they had little appendages like bladders, which enabled them to rise to the surface.*

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* Pelagian animals, so called by naturalists because they live in deep seas.

† The animals of this Order, to which Cuvier has given the name of *Cephalopodes*, from their feelers, which serve as feet, being attached to their heads, comprise several genera, as the *Sepia* or scuttle-fish, the calmar, &c. but these animals have no shells. There are only two known living species of Cephalopodes with chambered shells. The Argonauta, common in the Mediterranean, has an open unchambered shell. There are numerous minute microscopic chambered shells found in the present seas, but according to Cuvier the living animal has never yet been observed.—*Règne Animal*, tom. ii. p. 367.

Univalve unchambered spiral shells become numerous in the upper strata, probably from the circumstance that these strata were deposited under shallower seas. With respect to that class of the testaceous Moluscæ which did not enjoy the privilege of having heads and eyes, their motives for travelling, whether for pleasure or necessity, must have been few indeed; and they may be supposed to enjoy life as well in the deepest recesses of the ocean, as nearer its surface. The tenants of bivalve shells called by Cuvier *Acephales*,† have, however, a power of locomotion, which they effect, some by thrusting out a membrane called a foot, and with it they also attach themselves to rocks or other bodies, by a number of filaments called the Byssus, which they can remove at pleasure; but others have two tubes, with which they force out water with considerable violence, and impel themselves in an opposite direction; and others again, by a strong muscular action in opening and shutting their shells, can jump twelve inches at one leap.

All these modes of motion however, though sufficient for the wants of the animal, are very limited in their operation, and are equally adapted for animals in deep or shallow seas, in rivers or lakes: accordingly we find numerous testaceous Moluscæ of this class, both in the transition, the secondary, and the tertiary strata, and in our present seas and lakes, and at various depths.

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* All unchambered spiral shells were occupied by animals which had an organ of motion placed under the body, as in snails; they had heads, and they are called by Cuvier, *Gasteropodes*.

† Acephales—having no heads.

CHAPTER XI.

ON THE UPPER SECONDARY ROCKS.

On the Mineral and Zoological characters which distinguish Rocks of this Class.—Large Saurian Animals.—Magnesian Limestone or Dolomite.—On the occurrence of Magnesian Earth in Calcareous Rocks.—Compact and cellular Magnesian Limestone.—English Strata of Magnesian Limestone compared with those on the Continent of Europe.—Red Marle and Sandstone.—Variety of its Mineral characters.—The accordance of the English Strata of red Marle with those of France and Germany ascertained.—The red Marle and Sandstone of the Vosges.—English red Marle and Sandstone formed principally of the fragments of Trap Rocks and Transition Rocks, which formerly covered the midland parts of England.—Rock-salt and Gypsum.—The Gypsum accompanying Rock-salt originally anhydrous.—Rock-salt formations in various parts of the world.—On the invariable association of Gypsum with Rock-salt.

The upper secondary rocks in the present arrangement, comprise all the different formations above the great regular coal formation, and terminate with chalk, which is the uppermost formation of this class. The general mineral characters of the upper secondary strata may be briefly described; they are principally calcareous, though siliceous sandstone, and thick beds of sand and clay form parts of the series. The calcareous strata have an earthy appearance, but some traces of a crystalline structure are occasionally to be observed. No beds of good mineral coal are found in the upper secondary strata in England, and instances are rare of their occurrence in similar formations on the Continent. Neither metallic veins nor beds deserving notice, except of iron ores, occur in this class of rocks, nor do they afford any of the rare species of crystallized minerals. Rock-salt and gypsum are the most valuable minerals found in the upper secondary strata, and it is from them that all the important salt-springs issue. Some of the rocks in this class yield useful materials for architecture, but the stone is too generally soft and perishable. To the rocks of this class, Werner gave the name of flœtz or flat rocks, because in the northern parts of Europe they are generally arranged nearly in horizontal strata; but this character is altogether inapplicable to the upper secondary strata in the outer ranges of the Alps, and in the Jura chain, where they may be observed bent in every possible direction, and sometimes nearly vertical.

It has been stated in the preceding chapters, that the coal strata, which are interposed between the transition rocks and the upper secondary strata, contain almost exclusively the organic remains of vegetables; while the fossils in the lower or transition class, belong almost exclusively to marine animals. Another great change appears to have taken place in the condition of our planet after the deposition of the coal strata, for the upper secondary strata contain principally the remains of marine animals. It is in the strata belonging to this class, that the remains of vertebrated animals are first distinctly observed. Among these we find the bones of the mighty monsters of an ancient creation,—monsters whose extraordinary forms are still more astonishing than their immense magnitude. Some of these animals, of the saurian or lizard order, attained the length of forty feet or more, and appear, from the structure of the teeth and the organs of motion, to have united to the voracity of the crocodile, the power of darting through the water on their prey with inconceivable rapidity. Others, whose heads and bodies preserved the form of saurian animals, had necks so long, that when extended out of the water they mnst have resembled immense hydras. These animals had paddles in the place of feet, to accelerate their motion through water. Again, other large animals of this order had feet like those of the crocodile, and were probably amphibious: indeed the occurrence of large fossil vegetable stems in the same strata, proves that there was dry land in the vicinity.

It further appears, from the recent researches of Cuvier, that some of the lizard-shaped animals had wings, and realized the fabulous creations of the poet—they were flying dragons. The remains of the large saurian animals are more frequent in the middle part of the series, in the strata of this class, than in the upper or lower part; indeed, in the lowest members of this series they have not yet been discovered. It is truly remarkable, that throughout the whole series of the upper secondary strata, no bones of mammiferous land quadrupeds have yet been found, unless the strata at Stonesfield, present a solitary exception.

Lignite or wood-coal, and remains of vegetables, occur in some of the formations in this class, and also river shells.

In England, the order of succession of the upper secondary rocks may be more distinctly ascertained than in any other country that has yet been examined. I shall therefore describe them as they occur in our own country, with references to foreign localities, where the same beds or formations are well identified with the English strata. Geologists on the Continent, and particularly in France, had till very recently, no accurate knowledge respecting several of these formations; and their classifications of them are vague and contradictory.[*] More attention, however, has very lately been directed to this part of the geology of France; and the clear accounts which have been published by M. Beaumont in particular, of some of these formations, remove much of the obscurity which prevailed respecting them, and prove in a satisfactory manner the great similarity which may be observed in the similar formations of England and France.

Upper Secondary Class.

1. Magnesian limestone.
   - *a* Compact - - - *Zetchstein.*
   - *b* Cellular - - - *Rauche Wacke.*
   - *c* Conglomerate.
2. Red Marle and Sandstone.[†]
   - *a* Lower with Conglomerate and Porphyroidal Beds. } *Gres rouge ancien*, or *Rothtodte liegende.*

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[*] M. Humboldt and some other French geologists designate magnesian limestone by the name of *Calcaire Alpin.* But M. Bonnard applies the term to all secondary limestones, and even to our upper transition or mountain limestone: indeed his arrangement of these formations presents an inextricable tissue of confusion. It is greatly to be regretted that the Rev. W. D. Conybeare, after admitting that mountain limestone had nine characters in ten, common to transition limestone, should have been induced to create a new name for it, and that too, singularly inappropriate, '*Carboniferous limestone*;' for wherever this limestone appears, there is no good coal below it. By classing it, as it should be placed, with transition limestone, numerous mistakes would be avoided.

[†] This division of the red sandstone and also of the lias, is fully made out by M. L. E. de Beaumont, as will be stated hereafter.

b Middle - - - - -	*Gres des Vosges.*
c Upper with Rock Salt and Gypsum - - -	*Gres Bigarré.*
3. Lias Limestone and Lias Clay.	
a Lowest beds wanting in England - - - - -	*Muschelkalk.*
b Lias and Lias Clay - -	*Calcaire à gryphites.*
4. Oolite with subordinate Beds of Clay.*	
a Lower Oolite. Oxford or Clunch Clay. *b* Middle Oolites. Oaktree Clay. *c* Upper Oolites.	*Calcaires oolitiques*, of which the French now admit three divisions.
5. Sand, Sandstone, and Clay.	
a Iron Sand - - -	*Gres ferrugineux.*
b Weald Clay.	
c Green Sand - -	*Gres vert* and *Glauconie Crayeuse de Brongniart.*
6. Chalk.	
a Chalk Marle - - -	*Craie tufau de Brongniart.*
b Lower Chalk - - -	*Craie inferieure.*
c Upper Chalk - - -	*Craie superieure.*

Magnesian Limestone.—The geological position of this rock is immediately over the great coal formation, which it covers unconformably, and under the red marle and sandstone. When the magnesian limestone is absent, the red marle occupies its place: some geologists regard the magnesian limestone as an accidental formation in the red marle. Magnesian limestone is so called, because some of the beds contain a large portion of magnesia, combined with calcareous earth. The occurrence of magnesia as a constituent part of calcareous rocks, is not peculiar to this limestone; many limestones of the primitive and transition classes contain magnesia: it was first noticed by Dolomieu, and such limestones are called *Dolomites.* Primitive dolomite is minutely granular, and is generally so pulverulent, that it may be reduced to powder by the fingers. Transition dolomites, and the dolomites in the upper secondary strata, possess no well marked external characters, by which the presence of magnesia may be ascertained: they dissolve more slowly in acids than common limestone. The presence of magnesian earth in the proportion of nearly one half in certain limestones, is a fact that strongly militates against the theory which ascribes the formation of all limestone rocks to animal secretion; unless it shall be found that magnesian earth is contained in the shells and exuviæ of marine animals. I believe no analyses of shells or coral have yet been made, in order to ascertain the presence of magnesia as one of their constituent elements. Should magnesia be found in the exuviæ of certain orders of marine animals, and not in others, it would not only favour the opinion that limestone was of animal origin, but might also explain the cause of the alternation of beds of magnesian limestone with beds of common limestone in the same mountain. Or should shells of the same species contain magnesia, and others only calcareous earth, it would prove that under different circumstances, the same animal might form its shell of different constituent parts.

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* Many geologists class the oolites with the Jura limestone; but this classification is too indefinite, as the Jura limestone comprises several formations.

The magnesian limestone is distinctly stratified, the strata vary in thickness from a few inches to several feet; in the northern counties of England they are nearly horizontal, they border the great coal formation and cover it on the eastern side. This formation of limestone extends from the mouth of the Tyne to near Nottingham. The colour of the limestone is generally a yellowish or reddish brown, varying in intensity from a fawn colour to that of an overburnt brick. Some of the lowest beds are bluish and slaty, and intermixed with marle; but these beds do not rise to the surface in Durham, and their nature is little known. Some beds of magnesian limestone have a granular sandy structure, others are imperfectly crystalline; they possess a considerable degree of hardness. A cellular variety of this limestone occurs near Sunderland, which has received the name of Honeycomb limestone; it agrees in most of its characters with the rauche wacke of Thuringia, which is part of the zetchstein formation.

Many of the beds of this limestone yield a fœtid smell when struck with a hammer. The quantity of magnesia in the different beds of this limestone varies from 30 to 45 per cent, and some of the beds contain little or no magnesia. At Sunderland, the beds of magnesian limestone are more developed than in any other part of England that I am acquainted with. In an account I published of the Geology of Durham in the Philosophical Magazine for 1815, I estimated the total thickness at one hundred and fifty yards. Below the surface, this limestone has been bored into, to a considerable depth; the limestone was, as before mentioned, of a bluish colour. According to Mr. Farey, "under the yellow beds of magnesian limestone, there are several beds of compact blue limestone, abounding with Anomia (Terebratulæ) and other shells; some of these beds differ entirely from the yellow and red beds, and are more useful for agricultural purposes, particularly on the yellow limestone lands.*" The lower beds of this formation are, I believe, more fully developed in many parts of the continent than in this country, which occasions some uncertainty in classing them. The limestone of Thuringia, it is agreed by the most respectable geologists, is zetchstein, corresponding with our magnesian limestone; the lower part is a slaty marle, sometimes impregnated with bitumen, and sometimes with sand. This bed contains impressions of fish, like the lower beds of the slaty Sunderland magnesian limestone; it contains also a small quantity of copper pyrites, and the ores of lead, cobalt, zinc, bismuth, and arsenic, and is in some places worked by the miners for its mineral treasures. Above this bed there occurs a blackish gray compact limestone, very hard and tenacious, and distinctly stratified; over this is a cellular limestone; and above this, a blackish brown limestone, which yields a fœtid smell when struck with a hammer, and is in some places more than one hundred feet in thickness. All these different beds Humboldt comprises under the name of zetchstein, and agrees with other geologists in referring them to our magnesian limestone; the lowest bed rests on the red sandstone, and sometimes alternates with it; but according to some geologists, the connection between the two formations of red sandstone and zetchstein is such that they may be regarded as one formation. Several of the characters, particularly the zoological ones, appear rather more appropriate to the lias. Some beds abound in gryphites, (the Gryphæa aculeata,) and the remains of small saurian animals are found in them. The upper beds of zetchstein in Switzerland alternate with beds of gypsum, which is intermixed with rock-salt; at least they are generally described as zetchstein: some of the beds are argillaceous limestone, containing ammonites and belemnites, and appeared to me to have a greater resemblance to lias than to magnesian limestone.

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* Survey of Derbyshire, page 187.

In the lower part of the magnesian limestone in the West of England, there is a conglomerate limestone, which contains fragments of transition limestone, varying in size from several inches in diameter, to very minute grains.

The fossils in magnesian limestone are not numerous, at least in the upper beds. Neither gryphites, belemnites, nor ammonites, which occur in the zetchstein of Germany and Switzerland, have yet been discovered in this formation in England.

Magnesian limestone furnishes the most durable building stone that is any where found in the upper secondary strata.

I do not agree in opinion with those who regard the magnesian limestone districts as unfertile; and perhaps no parts of England are more salubrious than those which have a subsoil of this limestone.

A few small strings of lead ore have been found in the magnesian limestone rocks near Sunderland. The limestone rocks on the coast of Durham are wearing away by the violence of the ocean; they have evidently extended much further to the east than at present.

Red Marle and Sandstone.—The beds of this formation have generally the red colour which the name implies, but are often marked with irregular veins and spots, of a yellowish or bluish colour, and the sandstone is sometimes gray, with occasional spots of red.

The composition of different strata in this formation is extremely various: in some parts we find an argillaceous marle in different states of induration; in other parts we meet with regular strata of siliceous sandstone; and sometimes we have a conglomerate sandstone, or a soft sandstone, inclosing rounded pebbles of quartz and Lydian stone, as in the rock on which Nottingham and the Castle stand. In the lower part of this formation, the beds are porphyritic, and contain imperfect crystals of felspar; sometimes they pass into amygdaloid and trap. The fine siliceous sandstones, when closely examined, are often found to contain fragments of the neighbouring rocks: thus the sandstone in the vicinity of Charnwood Forest contains fragments of slate and chlorite slate; and the conglomerate beds on the northern side of that range of hills, are principally composed of fragments of granitic and slate rocks. No formation presents such a great variety of mineral characters as the red marle and sandstone, and geologists have frequently been greatly perplexed in their attempts to arrange and class the beds which occur in this formation. In England it has frequently been confounded with the red sandstone and conglomerate that occur under the upper transition limestone, called by English geologists the old red sandstone. But the old red sandstone of foreign geologists, or *roth-todte liegende*, the *gres ancien* of D'Aubuisson, covers the coal formation, and therefore corresponds with the lowest beds of the English red marle and sandstone.

Where the red marle formation is fully developed, it may be arranged under three divisions: the lower, which corresponds with the *roth-todte liegende*, consisting of fragments of different rocks cemented by sand or marle, and of beds of imperfect porphyry; the middle beds, consisting chiefly of sandstone, called by the French *gres rouge* and *gres de Vosges;* and the upper, consisting of marle and variegated sandstone, in which beds of rock-salt and gypsum occur; this corresponds with the *gres bigarré* of the French. In England the three divisions of this formation rarely if ever occur together accompanied with magnesian limestone; but it should appear from the situation of these different beds on the Continent, that the place of the magnesian limestone is between the lower and the middle division: the magnesian limestone or *zetchstein* rests on the conglomerate beds of red sandstone. In the third Number of the *Annales des Mines*, 1827, there is a very full account of the different arenaceous strata that separate the coal strata from lias limestone, along the feet of the Vosges mountains on the eastern side of France, by M. L. Elie de Beaumont.

This account throws considerable light on a part of geology, hitherto obscured by the conflicting opinions of former observers, and assimilates the red sandstone of France and Germany, with the different divisions of the same formation in England. The Vosges mountains are composed of granite and transition rocks, and at their feet there are several coal-fields: the coal strata, and also the lower declivities of the granite, are in part covered unconformably by nearly horizontal strata of red sandstone, and this is covered by lias limestone. We have here, on a larger scale, an exact correspondence with the geology of the Charnwood Forest district, where the granite and slate rocks are bordered by coal strata, and are both partly covered by horizontal strata of red marle and sandstone, and this again is covered by lias limestone. The red sandstone of the Vosges is however more developed; the lowest part consists of conglomerate and porphyroidal beds: these cover the coal strata; they agree in their mineral characters precisely with the conglomerates in the English red sandstone, particularly those of Devonshire, and are described by M. Beaumont as being the true *roth-todte liegende*. Above this occurs a considerable thickness of strata of red sandstone, which passes by gradation into the conglomerate; this is the proper *gres rouge:* it is designated by M. Beaumont *gres des Vosges;* it approaches in its character nearer to the *gres bigarré* than to the lower beds. The variegated sandstone, or *gres bigarré*, covers the *gres des Vosges;* but there appears to have been a considerable degradation of the surface of the *gres des Vosges*, and also a disturbance of the beds by subsidence or faults, before it was covered by the *gres bigarré* or variegated sandstone: nevertheless they are evidently members of the same formation. The *gres bigarré* is covered by an extensive formation of lias limestone in horizontal strata. In the sandstone of the Vosges, we have all the different divisions of the English red marle and sandstone brought together; and from hence it would appear, that the *gres ancien*, the *roth-todte liegende*, and the *gres bigarré*, which it has been hitherto difficult to assimilate with the English red marle and sandstone, are only the lower and upper parts of one formation, though they are sometimes separated by intervening beds of limestone.

The beds of red marle and sandstone of this formation, occupy a considerable part of the midland counties in England, extending from the eastern side of Yorkshire into Devonshire, and on the west, with some interruption, from Cumberland to Gloucestershire.

The beds or strata never attain any considerable elevation; they cover or inclose rocks of other formations: in Leicestershire and Warwickshire they surround rocks of sienite, granite, porphyry slate, greenstone, and quartz. The granite and greenstone of the Malvern Hills are covered on the southern side by the same red marle and sandstone. In Devonshire, several rocks of greenstone and amygdaloid trap are also surrounded by it; and at Rouvray in France, on the road to Dijon, I observed a low range of sienitic and granitic rocks, rising from a similar red marle, which like the English red marle, was covered by blue lias with gryphites. It was formerly maintained by Mr. Farey, that the sienitic and granite rocks of Charnwood Forest and Malvern, were merely anomalous masses in the red marle; and though this opinion was deemed extravagant, and afterwards abandoned by Mr. Farey himself, I am inclined to believe, that there is a greater connection between these different formations, than has hitherto been admitted.

The red marle and sandstone of England appear to me to have been principally formed by the disintegration of rocks of trap, greenstone, sienite, and granular quartz; the iron in the decomposing trap rocks has probably given to this formation its red colour; I conceive that the argillaceous marles have also been principally formed from the trap rocks, and the siliceous sandstone from the granular quartz rock. That rocks of sienite, trap, and quartz, were once extensively spread over the districts now covered with red marle, might I think be sufficiently established, by tracing them through the red marle districts, where they just peep above the surface, or they might be ascertained by sinking. The sienitic rocks of Charnwood Forest may be distinctly traced into Warwickshire; from thence to the Malvern Hills the connection may be followed; and from the Malvern Hills to the trap rocks in Gloucestershire, Somersetshire, and Devonshire; but every where accompanied by the red marle, or near to it. The quartz rock at the Lickey near Bromsgrove is not, as has hitherto been believed, the only rock of the kind in the midland counties; it may be found near Atherstone in Warwickshire, and is doubtless associated with the greenstone rocks in that neighbourhood, as members of the Charnwood Forest range of hills.*

I was informed by T. Johnstone, Esq. of Exeter, that he had frequently examined the red ground in the vicinity of the different trap rocks in Devonshire, and that he invariably found it composed of fragments of these rocks, increasing in size as he approached nearer to them. The sand rock on which Nottingham and Nottingham Castle are built, has evidently been formed of the ruins of more ancient rocks in its vicinity; and the rounded pebbles of white quartz and of Lydian stone, would indicate that they might have come from rocks formerly connected with the Charnwood Forest range. Still nearer the present hills, the finest sandstone contains fragments of slate, and the lower conglomerate is almost entirely composed of the fragments of those hills, as before observed. In the Vosges, the red sandstone every where accompanies the granitic and transition rocks, of which it also contains fragments. It must be recollected that the rocks which were the most disposed to decompose or disintegrate, would be the soonest worn down. We have no rocks of soft granite or sienite in England, like those of Auvergne or of the Forez mountains in France, and the reason why we have not, may be, that from their small magnitude they were probably carried away by those mighty inundations, that have swept over our present islands and continents. The Malvern Hills, the Lickey, the Charnwood Forest Hills, and the trap rocks in Gloucestershire, Somersetshire, and Devonshire, are the remaining nuclei of much larger ranges, as the scattered fragments in the adjacent, as well as in distant districts attest. If the red marle and sandstone in England, and in other countries, were formed of decomposing rocks of trap, granular quartz, porphyry, sienite and granite, the frequent occurrence of porphyroidal beds in this formation may admit of a probable explanation.

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* In the village of Hartshill near Atherstone, when the author was at school there, the quartz rock was employed in mending the roads; it is granular without cement, and breaks into sharp edged fragments; it has a light reddish colour. When a handful of the fragments is taken from the roads, and thrown upon the ground forcibly in the dark, they produce numerous scintillations like stars,—an experiment which has often excited the surprise of the author and his schoolmates.

It is not intended to maintain that every bed or stratum in this extensive formation is composed principally of the fragments of transition and trap rocks; but it may safely be affirmed, that there are few strata, in which some of these fragments may not be discovered.

The red marle produces some of the most fertile soils in England, which may be partly owing to its formation from soft trap rocks. Some basaltic rocks decompose rapidly, and are known to form soil favourable to vegetation; several basaltic rocks in Staffordshire decompose into a reddish brown clay, moderately tenacious.

The most valuable mineral substances found in the red marle are gypsum and rock-salt. The gypsum is both fibrous and massive; the fibrous gypsum forms numerous alternating seams in cliffs of red marle; the seams vary in thickness from one to three inches, and might be mistaken for strata, but they are irregular and of limited extent. In Nottinghamshire, the fibrous gypsum on the banks of the Trent is often beautifully white and translucent, and is accompanied with scales of chlorite, exactly similar to what I have observed in the beds of gypsum in the Valais in Switzerland. The white fibrous gypsum is employed by the paper-makers to whiten writing-paper.

Massive gypsum is granular; it occurs in irregular beds and blocks in the red marle, and is evidently a local formation. Anhydrous gypsum is occasionally met with in Nottinghamshire. Gypsum is associated with rock-salt wherever the latter mineral is found. In the Alps it is now discovered, that the gypsum when uncovered in its native beds is always anhydrous. Common gypsum contains twenty-one per cent of water. Anhydrous gypsum is entirely free from water, and is much harder and heavier than common gypsum. Should it prove a general fact, that the gypsum associated with rock-salt is always originally anhydrous, it might tend to elucidate the formation of both minerals; a subject which will be referred to, after describing some of the principal repositories of rock-salt.

Many repositories of rock-salt are situated near the feet of mountain ranges, and have probably been originally deposited in salt-water lakes: beds of rock-salt are now found at the bottom of some of the salt lakes in Africa. But though many salt formations are in comparatively low situations, there are others that occur at great altitudes, both in the Alps and the Cordilleras. In England, the principal beds of rock-salt are situated at a little distance from the western side of the range of hills, which separates the rivers that flow into the eastern and the western seas.

The rock-salt of Cheshire cannot properly be said to lie in or under the red sand rock before described, but is surrounded by it, and probably rests upon it; but as the lowest bed of salt has not been sunk through, this cannot be yet ascertained. The upper bed of rock-salt in that county is about forty-two yards below the surface: it is twenty-six yards thick, and is separated from the lower bed of salt, by a stratum of argillaceous stone ten yards thick. The lower salt has been penetrated forty yards. The upper bed was discovered about a hundred and forty years since, in searching for coal. Rock-salt at Northwich extends in a direction from N.E. to S.W. one mile and a half; its further extent in this direction has not been ascertained: its breadth is about fourteen hundred yards. In another part of Cheshire three beds of rock-salt have been found. The uppermost is four feet thick, the second twelve, and the lower has been penetrated twenty-five yards, but is not cut through. Besides the beds of rock-salt, numerous brine springs, containing more than twenty-five per cent of salt, rise in that country. The transparent specimens of rock-salt are nearly free from foreign impurities, and contain scarcely any water of crystallization.

In sea-water a large portion of muriate and sulphate of magnesia is found, which gives it that bitter nauseous taste, distinct from its saltness. This difference in the composition of sea-water and of rock-salt, might seem to indicate that rock-salt was not, as some suppose, produced by the evaporation of sea-water; but if it were formed in detached lakes, it is possible that the waters of these lakes, did not contain precisely the same salts in solution, as those of the sea. We know that the waters of some of the salt lakes existing at present, differ in their contents from sea-water. If, however, the evaporation were very slow, the salt of the ocean would separate from all its impurities by crystallization; these impurities being more deliquescent, might be washed away.

It may deserve notice, that few, if any, remains of marine or other organized bodies are found in the beds accompanying the rock-salt of Cheshire. In the Polish salt-mines, bivalve shells and the claws of crabs are met with in the upper strata of marle: and vegetable impressions in the bed covering the lower salt, at the depth of two hundred and twenty-five yards from the surface.

The salt formation at Droitwich in Worcestershire appears to be surrounded by the same kind of rock, and covered with similar beds of gypsum and marle, to that of Cheshire. Here the rock-salt, though its existence has been proved by boring, is no where worked. The salt is procured by evaporating the water, which is nearly saturated with it.

Salt springs rise in some of the coal strata adjacent to the red marle and sandstone; in all probability the brine is infiltered from that formation, into the basset edges of the strata overlying coal. There are salt springs in some of the coal-mines in Northumberland; and a spring of brine rises in the river Wear, in the county of Durham.

Brine springs, containing from five to six per cent of salt, rise in the coal-mines near Ashby-de-la-Zouch in Leicestershire, at the depth of two hundred and twenty-five yards under the surface. A weaker brine also rises in the upper strata: it springs through fissures in the coal, attended with a hissing noise occasioned by the emission of hydrogen gas.

I examined these mines belonging to the Earl of Moira in the summer of 1812: they are situated at Ashby Wolds, in the very centre of England;* and what may appear remarkable in this situation, they are worked one hundred and forty yards below the level of the sea, which is ascertained from the levels of the canal that passes by the pits. Had this circumstance been known before the attention of geologists was directed to the structure of the earth's surface, it would have been inferred, that brine springs so far below the level of the sea, had their source from the waters of the ocean, percolating through fissures in the earth.

There are many salt springs in France, but no mines of rock-salt. The salt springs at Salins in the department of the Jura, rise in the red marle formation; and the gypsum with which they are associated is exactly similar to the massive gypsum in the English red marle. The strongest of these springs contains fifteen per cent of salt.

In Switzerland the rock-salt and gypsum do not occur in the red marle, but between calcareous beds, which are, I believe, analogous to the English lias, and will be again mentioned.

In Spain there are several salt springs and beds of rock-salt: the principal formation of rock-salt at Cardona in Catalonia has been described by Count Alexander Laborde, in his magnificent work entitled *Voyages Pittoresques dans l'Espagne.*

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* Baths and hotels are now erected there for the accommodation of visiters; they are called the Moira Baths, near Ashby-de-la-Zouch.

"The salt district of Cardona comprehends the hill on which the town is situated, and the environs of more than a league in circumference. The surface is almost every where covered with vegetable soil to the depth of six inches or more, which renders it productive. The place where the rock-salt is procured is a valley forming an oval, about one mile and a half in length, and half a mile in breadth from east to west, extending from the Castle of Cardona to the promontory of red salt at the other end. The last is the most considerable of the salt rocks, and has not yet been worked; it is six hundred and sixty three feet in height, and twelve hundred and twenty feet in breadth at its base. This valley is also traversed by a chain of hills of rock-salt: besides these, there are other rocks of salt at the feet of the fortress, and upon the declivity of the mountain which stretches to the fountain called Cancunillo. The mountain of red salt is so called because that colour predominates; but the colours vary with the altitude of the sun, and the greater or less quantity of rain. At the foot of this mountain a spring of water issues, which comes through a fissure we perceive on the summit. The rivulet runs all along the valley from the east, but passes under ground in part of its course, particularly under the hill where the rock-salt is mined; it rises again to the surface at a little distance, and, after running along the plain, discharges itself into the river Cardona. This brook in rainy seasons swells the waters of the river, which then become salt, and destroy the fish; but at three leagues lower, the water has no perceptible taste of salt. All these salt-mountains are intersected by crevices and chasms; and have also spacious grottoes, where are found stalactites of salt, shaped like bunches of grapes, and of various colours." "Nothing can compare with the magnificence of the spectacle which the mountain of Cardona exhibits at sunrise. Besides the beautiful forms which it presents, it appears to rise above the river like a mountain of precious gems, displaying the various colours produced by the refraction of the solar rays through a prism."

Hungary and Poland afford the most numerous and extensive repositories of rock-salt in Europe. The salt-mines of Wielelska near Cracovia have been long celebrated and frequently described; they are worked at the depth of seven hundred and fifty feet. The rock-salt is covered by alternate beds of marle and conglomerate; blocks of salt occur also in the marle. The beds of rock-salt are inclined at an angle of forty degrees. It is remarkable, that in these mines of rock-salt, there are springs of fresh as well as of salt water. At Paraid in Transylvania, there is a valley the bottom and sides of which are pure rock-salt. The mine of Eperies is about nine hundred and ninety feet deep. Water is sometimes inclosed in the blocks of rock-salt."—*Brongniart, Mineralogie.*

There is an extensive formation of rock-salt, stretching on each side of the Carpathian Mountains for six hundred miles, from Welielska in Poland towards the north, to Rimnie in Moldavia on the south. It has indeed been observed that rock-salt and brine-springs most generally occur near the feet of extensive mountain ranges, which adds probability to the opinion, that these ranges were once the boundaries of extensive salt lakes.

In the lofty deserts of Caramania in Asia, according to Chardin, rock-salt is so abundant, and the atmosphere so dry, that the inhabitants use it as stone, for building their houses. This mineral is also found on the whole elevated table-land of Great Tartary, Thibet, and Indostan. Extensive plains in Persia are covered with a saline efflorescence; and according to the account of travellers, the island of Ormus, in the Persian Gulf, is one large mass of rock-salt.

In the elevated mountains of Peru, rock-salt is said to occur at the height of nine thousand feet above the level of the sea. In North America there are various salt-springs called Licks, because the herds of wild cattle formerly repaired to them, to lick the soil impregnated with salt. Near to these places the immense bones of the great Mastodon are frequently found at a small depth below the surface. According to the account of Hornemann, there is a mass of rock-salt spread over the mountains that bound the desert of Libya to the north, so vast that no eye can reach its termination in one direction; and its breadth he computed to be several miles. Rock-salt has also been found in New South Wales.

It would exceed the limits intended for the present volume, to enumerate the different places in which this valuable mineral occurs. I only propose to note the more remarkable situations presenting phenomena that may tend to illustrate the mode of its formation. Among these should not be omitted the salt lakes on the borders of Caffraria, east of the Cape of Good Hope, which contain at their bottom, thick beds of rock-salt variously coloured,

There is a remarkable formation of salt at Posa near Burgos, in Castille, placed in an immense crater of an extinct volcano, in which are found pumice-stone and puzzolana. The volcanic mountain of Cologero near Sciacca, in Sicily, contains in its beds a considerable intermixture of common salt, and masses of rock-salt occur in other parts of the island, imbedded in clay.* In these and in some other instances, it is probable that subterranean fire may have been an active agent in the formation of rock-salt, by evaporating the waters of salt lakes, or of countries recently emerged from the ocean.

The rapid formation of rock-salt in Syria, during one of those igneous eruptions which have at times overwhelmed certain portions of the globe, is, perhaps, obscurely alluded to by the sacred writer who has narrated the early history of the human race. Gen. chap. xix.† The salt lakes existing in that country are well known.

Whether all the repositories of rock-salt above enumerated occur in the red marle, cannot in the present state of our information be accurately ascertained. The great formation of rock-salt and gypsum near Bex in Switzerland, constitutes two large and extensive beds. The lowest rests upon black limestone, argillaceous limestone, and sandstone; and between the lower gypsum and the upper, there are thick beds of argillaceous limestone, and similar argillaceous limestone forms caps over the upper gypsum. The gypsum in the large beds is anhydrous, and contains particles of rock-salt and common gypsum disseminated through it. The prevailing fossils are ammonites and belemnites. —(Travels in the Tarentaise, p. 415.)

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* Travels in Sicily, by Lieut. Gen. Cockburn.

† Jerome, who resided in Syria in the fourth century, informs us, that the rock of salt was existing in his time; and fancifully relates certain peculiarities respecting it, which equal in absurdity the legends of the darkest ages of papal superstition.

The mineral characters of the strata at Bex, and the imbedded fossils, incline me rather to refer the argillaceous limestone, over and under the gypsum and salt beds, to the English lias, than to magnesian limestone.

The saliferous gypsum in the Tarentaise is also anhydrous, and contains a considerable quantity of silex; it occurs interstratified with limestone, which bears a nearer resemblance to the magnesian limestone, than to lias. The tops of some of the mountains are covered with beds of common gypsum, intermixed with native sulphur. In one of the rocks associated with the gypsum formation, I discovered a fossil Patella. Though a branch of the *Ecole des Mines*, with able instructors from Paris, had been for some years established at Moutiers, close to the salt formations, a very erroneous opinion respecting the gypsum of the Tarentaise was maintained by the professors; namely, that the gypsum merely formed an unconformable covering over the adjacent mountains. I observed it in several parts of the valley of the Doron near Moutiers, as distinctly interstratified in the calcareous mountains, as the gypsum of Montmartre is interstratified between the tertiary formations near Paris. In one of the beds of gypsum, there was a thin stratum of carbonaceous matter, which soiled the fingers like coal smut; this is the only instance of carbonaceous matter found in gypsum, that I am acquainted with.

Transparent colourless rock-salt consists of muriate of soda, nearly in the highest state of purity; or, according to Sir H. Davy, of chlorine and sodium. It has so little water of crystallization, that it scarcely decrepitates when thrown on burning coals, in which it differs from salt prepared artificially by evaporation. Specimens of rock-salt brought from the Polish mines, are less disposed to deliquesce than those from Cheshire. The deep red colour very common to rock-salt is derived from the oxide of iron. Clay or marle commonly accompanies rock-salt; it frequently lies imbedded in clay in detached masses; the clay is often much impregnated with salt, which is extracted from it by solution in water. The almost constant occurrence of sulphate of lime (gypsum) with rock-salt, is also a fact of considerable interest. It is curious to observe the two most powerful acids, the sulphuric and muriatic, so nearly associated in the same place. This fact, in a more advanced state of science, may elucidate the chemical changes which have effected the formation of these minerals.

The most natural hypothesis respecting the formation of rock-salt, at least in some situations, is that before stated, which attributes it to the gradual evaporation of lakes and pools of salt water, which remained, when the ocean retired from the present continents. This mineral by slow evaporation would be separated from the impure salts that exist in sea water; and as these salts are more deliquescent than rock-salt, they might be washed away, before the beds of rock-salt were covered with earthy strata.

The occurrence of anhydrous gypsum with rock-salt, which is also anhydrous, would, however, indicate the action of heat in the formation of these minerals; for it is scarcely possible to conceive any mode of aqueous deposition that could form anhydrous gypsum: but common gypsum might be fused by heat, and its water of crystallization expelled; it would then be converted into anhydrous gypsum. From the observations of Charpentier at Bex, it appears that the great beds of gypsum associated with rock-salt, are always found to be anhydrous when they are laid open to the atmosphere, but they soon absorb water, and are converted into common gypsum. The saliferous gypsum in other parts of the Alps, is also anhydrous; and if it should appear that the beds of gypsum associated with rock-salt in other countries are anhydrous, where they have not been exposed to the action of moisture, it would add much probability to the opinion, that the consolidation of rock-salt and gypsum had been effected by heat.

Before concluding the account of the red marle and sandstone formation, it may be proper to state, that foreign geologists contend for the existence of a red sandstone over coal, which is laid conformably with the coal strata, and is a part of that formation.[*] If such a red sandstone, distinct from the new red sandstone, exist any where in England, it is near Oldham and Rochdale in Lancashire. The sandstone of Lancashire is coloured in Mr. Greenough's Geological Map of England, as the new red sandstone, and in Mr. Smith's Geological Map, as the old red sandstone; but I am inclined to believe, that the true position (*gisement*) of this sandstone in many parts of Lancashire, is not yet ascertained: its relations with the coal strata are different from those of the new red sandstone in other parts of England. I propose to revert to this subject in a subsequent chapter.

A very remarkable discovery has been recently made of the foot-marks of some unknown quadruped in strata of new red sandstone, at the Corn Cockle Muir, three miles from Lochmaben in Dumfriesshire. They were found forty-five feet under the present surface; the strata are inclined 37 degrees. This circumstance was communicated to the author by Mr. Murray, jun. of Albemarle-street, who showed him at the same time a plaster cast, taken from a slab of stone, in which the impressions were tolerably distinct, and also part of a thin stratum of the stone itself, with indistinct impressions of a similar kind. There can scarcely be a doubt, that they were the real foot-marks of a digitated animal having short toes and claws, and the foot broad in proportion to its length. The breadth of the foot is above one inch. The part of the sandstone in Mr. Murray's possession appeared principally composed of granular fragments of reddish quartz rock and felspar, with spots of chlorite or hornblende. As remains of reptiles have been found in the zetchstein or magnesian limestone on the Continent, which is as ancient as the new red sandstone, may not this animal have been a reptile allied to the tortoise?

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[*] Le Gres, masse principale de terrain houiller, prende souvent une grand extension, en abandonnant au moins en majeure partie la houille avec l'argile schisteuse qui l'envelloppe.—*D'Aubuisson, Traité de Geognosie, tom.* 2.

M. A. H. Bonnard, in his *Apperçu Geognostique des Terrains*, p. 144, describes the red sandstone as the upper part of the coal formation.

A. Humboldt, in his *Essai Geognostique sur le Gisement des Roches*, p. 199, mentions a red sandstone passing into porphyry, as the upper part of the coal formation in Germany.

Messrs. D'Aubuisson and Bonnard appear to have mistaken the lowest part of the red marle and sandstone, for a portion of the regular coal strata. M. Humboldt makes a distinction between the unconformable red sandstone and the porphyritic red sandstone, which he cites as a part of the regular coal formation.

CHAPTER XII.

ON PART OF THE UPPER SECONDARY STRATA, COMPRISING LIAS CLAY AND LIMESTONE, AND THE OOLITIC SERIES.

Mineral Characters of Lias Clay and Limestone.—Alum Slate.—Zoological Characters of Lias.—The Muschelkalk of France and Germany, the lower part of the Lias Formation, wanting in England.—Lias of the Alps.—Oolite or Roestone, the Jura Limestone of Foreign Geologists.—Mineral and Zoological Characters of Oolite or Roestone.—The lower, middle, and upper Oolites.—Oxford or Clunch Clay.—Stonesfield Slate, with Organic Remains of Insects, Birds, and Land Quadrupeds.—Extent of the Oolite Formation in England; its sudden termination: Observations respecting it.—Foreign Oolites.

THE great bed of dark bluish clay, accompanying numerous thin strata of dark argillaceous limestone, called lias, is the best characterized of all the upper secondary formations in England, except chalk; and it preserves the same appearance throughout a considerable part of France; and may also be traced, but with some diversity of character, into Switzerland and Germany.

The name Lias appears to have been given to it by a provincial pronunciation of the word *layers;* as the lias limestone strata are generally very regular and flat, and rise in thin slabs or layers when got from the quarry. Where the lias beds are pretty fully developed, they form a mass of stratified limestone and clay, several hundred feet in thickness, which rests upon the red marle described in the preceding chapter.

The regularly stratified lias limestone occupies the lower part of the bed, and the lias clay the upper. The lower beds of the limestone have often a yellowish white colour, and are called white lias. The blue lias limestone has generally a dark smoke-grey colour, a dull earthy texture, and an imperfectly conchoidal fracture: the purest beds contain from eighty to ninety per cent. of carbonate of lime, combined with bitumen, alumine, and iron. If iron enter largely into the composition of this limestone, it forms a lime, when burned, which has the property of setting under water.

The finer kinds of white lias will receive a polish, and may be used for lithographic drawings.

The lias clay frequently occurs in the form of soft slate or shale, which divides into very thin laminæ. This shale is often much impregnated with bitumen and with iron pyrites, and will continue to burn slowly when laid in heaps with faggots, and once ignited: during this slow combustion, the sulphur in the iron pyrites is decomposed, and combines with the oxygen of the atmosphere and with a portion of the alumine in the shale, and forms sulphate of alumine or alum. The alum shale of Whitby in Yorkshire is of this kind; it has rather a soapy feel, and a slight silky lustre. When the lias clay or alum shale falls in large masses from the cliffs upon the sea shore, and gets moistened by sea water, it ignites spontaneously, and continues burning a considerable time. The cliffs of lias clay near Lyme in Dorsetshire, took fire after heavy rains, and continued burning for several months, about the middle of the last century; and at the present time the cliffs near Weymouth are ignited by a similar cause. The composition of the clay in those cliffs is nearly the same as in the lias clay; but it is an upper formation, called Oxford or clunch clay.

Lias clay is impregnated with a considerable portion of muriate of soda, and sulphate of magnesia, and soda. The mineral springs of Cheltenham and Gloucester rise in this clay; but the mineral qualities decrease after the springs have been opened some time, which proves that the saline matter is derived from parts of the bed adjacent to the springs, and is therefore soon exhausted.

The beds of lias clay and limestone are particularly distinguished by the number and variety of the organic remains which they contain. Twenty different kinds of ammonites have been discovered in lias, and also various other species of chambered shells, nautilites, and belemnites. Univalve shells are not numerous in this formation, but a great variety of bivalve shells occur in it.

The gryphite (*Gryphea arcuata*) abounds so much in some of the beds of lias, that in France it has received the name of *Calcaire à gryphites.* Pentacrinites also abound in the upper part of the lias, and in conjunction with gryphites and the ammonites that have a ridge between two furrows, round the back of the shell, are characteristic of the lias formation.

The most remarkable organic remains are, however, certain species of fish, and those of vertebrated animals allied to the order of lizards; the fossil fish are generally found in the middle of flattened balls of limestone, in which the form of the body and the scales is often well preserved. The saurian or lizard-shaped animals have left no trace of the form of their bodies, except what can be ascertained from the remaining skeletons. To the Rev. W. D. Conybeare we are indebted for having determined the forms of two genera of these animals. The ichthyosaurus or fish-lizard had the head of a lizard, with a very long pointed muzzle, and numerous conical teeth; the orbit of the eye is uncommonly large. Some idea may be formed of the magnitude of these animals, when I mention that the orbit of the eye in a head, belonging to Mr. Johnson of Bristol, which I measured, was ten inches long and seven broad: the orbit in another head, belonging to the same gentleman, measured nine inches in breadth.* The vertebræ of the ichthyosaurus resemble those of a shark, which enabled it to bend its tail with great facility, and assisted the motion of its paddles, in propelling the body with great velocity through water. Of the ichthyosaurus, four species have been discovered. The plesiosaurus resembled the former genus in many important parts of its osteology; but its vertebræ had a closer approximation to those of the crocodile; they are only slightly concave: its neck was longer than its body, and was composed of thirty vertebræ, which exceeds the number of the cervical vertebræ of the swan. Five species of these animals have been determined; some of them were twenty feet in length. The bones of these animals are found very commonly in the cliffs of lias at Lyme in Dorsetshire, and on the southern bank of the Severn. It is not certain that any bones of the crocodile genus which had feet have been found in lias; but bones of the turtle sometimes occur in it. Vegetable remains in lias consist of fossilized wood and jet.

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* Mr. Johnson of Bristol has, during many years, devoted much time and labour, and has liberally expended considerable sums of money in collecting organic remains of these saurian animals; and it is to the collection of these remains in his private museum, that we are principally indebted for the discoveries which have been made respecting them.

The lias formation extends in a waving line through England, from near Whitby in Yorkshire to Lyme in Dorsetshire; at both its extremities it is fully developed, and presents similar features, namely,—dark cliffs of blackish clay or alum shale, with a nearly flat floor of lias limestone extending into the sea, forming a natural pavement, on which the observer may walk secure, treading at almost every step on the organic remains of the inhabitants of a former world, disseminated through the rock: these animal remains are generally surrounded by stone harder than the other part of the stratum, and project above the surface. At Sandsend, near Whitby, the alum shale has been perforated near the sea, to the depth of one hundred and thirty yards, without penetrating into the subjacent rock; to which if we add the height of the cliffs above, it will make a total thickness of lias exceeding two hundred and twenty yards: the upper parts are more productive of alum than the lower. In Dorsetshire the whole thickness of the lias formation may be seen in succession; a few miles west of Bridport, the uppermost bed rises above the level of the sea: three miles west of Lyme it terminates, and the white lias (the lowest part of this formation) may be observed at low water resting on red marle.

From the observations of M. Elie de Beaumont on the lias near the Vosges mountains, it appears that in the lias of France there are certain lower strata nearly filled with shells, and which contain that beautiful fossil the Lily Encrinite. These strata are wanting in every part of the English lias that has yet been examined: it is to this part of the lias that the name *muschelkalk* has been given by the Germans, and it has frequently been described as a different formation from lias; but M. Beaumont says that the strata above the muschelkalk are the *calcaire à gryphites*, and that the lower and the upper strata are undoubtedly parts of the same formation, lying between the red marle, *gres bigarré*, and the oolites; and he describes this to be the case with the muschelkalk in Germany, the lower beds of which also contain the lily encrinite. We have here a key to certain parts of foreign geology, which have hitherto been somewhat obscure: the muschelkalk and the lias are not, as has been often stated, different formations, but are only different parts of the same bed; for the description of M. Beaumont is so precise, as to leave no doubt respecting the identity of the English lias and the French *calcaire à gryphites*, and that the latter and the muschelkalk are only upper and lower strata of lias. In England, lias limestone occurs almost always in nearly horizontal strata, and never attains any great elevation. On the west of Gloucester, at Highnam Park, lias limestone forms a nearly flat pavement, on the summit of a hill about two hundred and fifty feet above the level of the Vale of Severn: from this point to the north-west there is no bed of lias known in England or Wales; but it is found in the north-west part of Ireland, and in some of the Hebrides. At Barrow-on-Soar in Leicestershire, lias rises considerably above the level of the river: it is in the flattened balls that occur in the Barrow limestone, that the finest specimens of fossil fish are found. The lias clay, from its comparative softness, has frequently been excavated into valleys,—some of the mountain valleys in the Alps are cut in lias clay. The lias limestone of the Alps and the Jura, loses its flat and parallel stratification, and is bent and contorted in various directions: it also frequently loses its earthy texture, and is hard and semicrystalline, like transition limestone.

The Rev. R. Halifax, of Standish, near Gloucester, obligingly showed me part of the lias and oolite beds in the vicinity of Cheltenham, which he had particularly studied. Between the upper lias clay and the oolite, there is a thick bed of reddish earth with ferruginous nodules inclosing portions of lias; this earth may be seen cropping out at the foot of Leckhampton Hill. No well marked natural division exists, which can determine whether this bed should be classed with lias, or the oolites. The fossils in lias clay and limestone are nearly black, and are sometimes incrusted with pyrites.

The most valuable mineral substances obtained from lias in England, are water-setting lime and alum shale. The property of setting under water may be communicated to any kind of lime, by an admixture with burned and pulverized ironstone. Many of the bituminous and pyritical shales in the coal strata would yield alum by slow combustion, if they could be obtained with facility. When alum shale is burned, and the soluble part is extracted by water, it is necessary to add potass before the process of evaporation, as crystallized alum is a triple salt, composed of sulphate of alumine and potass.

Oolite.—The numerous beds of yellowish limestone alternating with beds of clay, marle, sand, and sandstone, that compose the oolite formation in England, are of variable thickness; but their aggregate average depth, from the top of the upper oolite to the lias, may be estimated at one thousand feet. These beds may be traced with little interruption along a waving line from the Cleveland Hills in Yorkshire, into Dorsetshire. In Gloucestershire they compose a lofty range of hills on the south side of the Vale of Severn, called the Cotteswold Hills; but no strata of this formation are found in any part of England or Wales, northwest of the river Severn. In many parts of France, the oolite strata accompanied with lias, present all the characters of the same formations in England; but in the Jura mountains, where they are fully developed, the mineral characters often differ considerably; and it is only from the geological position and the imbedded fossils, that they can be identified with the English series.

Oolite or Roestone receives its name from the small globules like the roe of a fish, that are imbedded in many of the strata; in some instances these globules attain the size of a pea, and this variety has obtained the name of *Pisiform oolite.* In England, nearly all the beds of limestone that are oolitic, in this formation, have a yellowish brown or ochery colour, by which they may at first sight be distinguished from lias. The limestone in which the globules are imbedded has generally an earthy texture, and is dull and incapable of receiving a polish; some varieties of oolite have been much used for architecture. St. Paul's, Somerset House, and many of the public buildings in London, are constructed of this stone; but it is not durable. The occurrence of small oviform globules in limestone is not exclusively confined to the oolite formation; in the magnesian limestone, and even in transition limestone, a tendency to an oolitic structure may sometimes be observed. It is not yet ascertained whether these globules are the result of a tendency to crystalline arrangement, or whether they are of animal origin.

The organic remains that occur in the different beds of oolite are so numerous and various, that it would require an ample volume to describe them fully. It will however be necessary to notice those fossil genera that differ remarkably from the genera whose remains are found in the lower strata, and indicate a considerable change in the condition of the globe, or at least in those parts of it where the strata were deposited.

It has been already observed, that the univalve shells in the lower strata were chiefly different species of Nautilites, Ammonites, and Belemnites, which are chambered, and that univalve unchambered shells were rarely found among them. By far the greater number of genera that have left their remains in these strata belong to the acephalous moluscæ, or such as had neither heads nor eyes, and inhabited bivalve shells. Even in the lias, only four genera of unchambered univalve shells have been found,* and the individual shells of each genus are very rare; but in the oolite, the genera and species of univalve unchambered shells are more numerous, and the individual shells of several species abound in some of the strata. Now, as these animals had heads and eyes, and moved on their bellies like the land-snail, we may infer that they did not live in deep seas, where the sense of vision could not be available; they lived and moved in comparatively shallow water near the shore.

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* The Helicina, 3 species; the Trochus, 8 species; the Tornatella, and the Melania.

The vertebrated animals, whose remains are found in oolite, are some of them of the same genera as those discovered in lias; but others belong to the crocodile genus, and had feet, like the living species of crocodiles, and were probably amphibious: hence we may infer, that there were dry land and rivers in the vicinity.

It may well excite surprise, that calcareous strata should so rarely be found which present distinct indications of having been formed exclusively by coralline polypi, particularly as coral rocks and reefs of great extent are so rapidly forming in our present seas. There are however, among the strata of oolite, some which are almost entirely composed of madreporites, and have received the name of coral ragg. There are other strata which abound in the remains of fossil sponges and alcyonia, and with congeries of minute millepores and madrepores. Nearly twenty species of trochiform or top-shaped spiral shells, and several species of echinites, are found in the oolite strata; but in the lias below, only a few species occur, and the individual shells are scarce. The *Gryphea arcuata*, so common in the lias, is rarely if ever found in the oolite strata; but another species, with an expanded shell, called the *Gryphea dilata*, is a fossil frequently found in different beds of the oolite formation. The shells and bones in the oolite limestone have the yellowish ochery colour of the stone in which they are imbedded, which may serve at once to distinguish them from the lias fossils, that invariably partake of the dark colour of the beds in which they occur. English geologists make three divisions of the oolite formation,—the *upper*, the *middle*, and the *lower*: they are separated by thick beds of clay, and some variety may be observed in the fossils of each division, but the general characters are nearly the same; and in an elementary treatise, a too minute description would only perplex the student, particularly as some of the beds appear to be of limited extent.

The *lower division* of *oolite* comprises; 1st, an imperfect dark brown limestone, much intermixed with sand and the oxide of iron; 2dly, beds of sterile clay and fullers-earth; and, 3dly, the great oolite, which is of considerable thickness, and yields freestone for architecture: it is composed of minute globules and broken shells, united by a yellowish earthy calcareous cement. With the lower division of oolites may also be classed, 4thly, the Stonesfield slate, which is a sandy calcareous stone, dividing into thin strata, accompanied with shale and carbonaceous matter. 5thly, forest marble: the beds are not numerous, and are chiefly composed of large fragments of shells; small entire turbinated shells abound in some of the strata. It deserves attention, that the univalve shells are most frequent in the thin beds, and the bivalves in the thicker beds, of this stone. 6thly, cornbrash. This is the upper part of the lower division of oolites; it does not compose beds of any considerable thickness, nor does it frequently occur in regular strata of any great extent, but generally in detached masses, cemented by clay: the external part of the stone is brown, but the inner part has often a gray or bluish colour. To Mr. Wm. Smith we are principally indebted for the first accurate account of the different beds of the oolite formation: he observed that though the total thickness of the cornbrash beds is but small, there is a considerable difference between the fossils in the upper beds and those in the lower ones.

Between the lower and the middle division of oolites, there are beds of dark blue clay called *Oxford* or *Clunch clay;* the thickness has been estimated at two hundred feet. Some of the beds are bituminous, and bear a near resemblance to lias clay; they abound in Septaria: other beds are much intermixed with calcareous earth. In the lower part of the Oxford clay, irregular beds of limestone occur, which have received the name of Kelloway rock, from being found near Kelloway bridge, in Wiltshire. The bones of one species of ichthyosaurus, different from those in the lias, have been found in the Oxford clay.

The MIDDLE DIVISION *of oolite* consists, 1st, of beds of siliceous and calcareous sand: 2ndly, the coral ragg composed of loose earthy limestone, sometimes entirely formed of several species of branching madrepores; and 3rdly, the upper oolite: this agrees in many of its characters with the great oolite, but is more perishable; in some of the beds, the oolitic character is scarcely discernible, in other beds the globules are as large as peas; it has hence received the name of Pisolite. The total thickness of all the beds in this division has been estimated at two hundred feet.

Between the Middle and the Upper division of oolites, there occurs another thick bed of clay, which has received the name of Kimmeridge clay. It is a grayish clay passing into the state of shale, and is sometimes so bituminous as to be used for fuel; its thickness in some parts is more than one hundred feet. Bones of saurian or lizard-shaped animals have been found in this clay, and also bones of animals of a higher order allied to the whale or seal.

The UPPER DIVISION *of oolite* comprises the beds of Portland stone, which have been well described as a calcareo-siliceous freestone, with beds and nodules of flint. In the Isle of Portland, where the middle bed of the Portland stone is quarried for architectural purposes, it is covered by a cream-coloured stone called *cap*, which is only burned for lime: under this, there are two beds of workable stone, each five feet thick, separated by gray flint, and a third bed of the best stone below. The total thickness of the three beds of building stone varies from seventeen to twenty-four feet. The Purbeck beds are by some geologists classed with the oolites; but they may more properly be regarded as a distinct formation, belonging to the iron-sand, as the fossils contained in these beds differ much from those in the oolite, and are supposed to be fresh water shells.

The calcareous sandy slate of Stonesfield, near Woodstock in Oxfordshire, is believed to form a member of the lower oolitic series; but its organic remains are so different from those in any known beds of oolite, that until it can be seen actually covered by some undisputed member of the oolite series, a doubt must be entertained whether it may not be a portion of a more recent formation out of its place, as we find chalk occasionally beyond the limits generally assigned to it.

The Stonesfield slate consists of two beds of yellowish or grayish oolitic limestone, each about two feet thick, and separated by a bed of loose calcareous sandstone about the same thickness. The Stonesfield slate on exposure to frost divides into thin plates, which are used for roofing. The stone is obtained by working horizontal galleries in the hill, which galleries communicate with deep perpendicular shafts. It is to be regretted that no account has been yet published of the different strata of stone sunk through by these shafts, as we might hence derive decisive evidence, respecting the true geological position of the Stonesfield slate.

The fossil remains in the Stonesfield slate, consist of the impressions of the outer cases or elytra of winged insects, and the bones of animals of the opossum or diadelphis genus, and also the bones of the megalosaurus or gigantic lizard, supposed to be analogous to the Monitor. From the size of these bones, it is estimated that the animal to which they belonged, was forty feet in length and twelve feet high. Legs and thigh bones of birds are also found in the Stonesfield slate, with the teeth, palates, and vertebræ of fishes, and two or three varieties of crabs and lobsters. Several varieties of marine shells and of plants occur in the same beds. The most remarkable circumstance attending these fossil remains is, that they should occur in strata which are generally believed to have been deposited before the creation of terrestrial mammalia. If, however, there were islands, inhabited by the higher class of animals, when the oolite beds were forming, their bones may have been carried down by rivers into the sea, and deposited with those of marine animals. But though this hypothesis might satisfactorily explain the occurrence of these remains in the Stonesfield slate, it would still be not less extraordinary, that similar remains should have been no where found in any of the upper secondary strata in England, nor in other countries; and that they are never met with, except in strata considerably above the chalk formation. The occurrence of wood, and beds of lignite (or wood coal) in oolite, confirms the opinion that dry land existed somewhere in the vicinity at the period when the oolitic beds were formed or deposited; but no indication that the land was inhabited by terrestrial quadrupeds has been hitherto discovered, except in the slate of Stonesfield. In the strata above the oolite, particularly in the iron-sand of Cuckfield, the bones of the megalosaurus and crocodile, and those of turtles, birds, and fish, present a similarity to the fossils of Stonesfield; but the bones of terrestrial quadrupeds are wanting, and many of the shells are fluviatile. But where was the island on which the animals lived and flourished, that have left their bones in the strata of Stonesfield? This question will be considered in the brief chapter I propose to give of the Geology of England.

OBSERVATIONS.

The oolites on the continent are frequently accompanied with beds of lignite: in England, lignite is not found in oolite, but in the thick beds of clay which separate the upper and the middle divisions of this formation. In returning from the county of Durham, in 1820, I took a hasty morning survey of the oolite of the Cleveland Hills in Yorkshire, in the immediate vicinity of Thirk. I had not time to visit the coal mines; but from the specimens of coal I saw lying by the road side, I should consider it as a lignite, and not a true mineral coal: it is chiefly employed in burning lime, and is not used for domestic purposes, except by the poor. The oolite of the Cleveland Hills inclines to a light smoke-gray colour; it is distinctly oolitic; the stone is more compact and hard than the oolites of Oxfordshire or Gloucestershire, and bears a near resemblance to some of the limestone beds on the Jura, which I saw the same summer. The Cleveland oolite appears to rest immediately on a sandy red earth, like that over the lias near Cheltenham, and according to the account of the quarrymen, the bed below is a dark soft shale, which they considered to be the same as the alum shale (*lias*) on the north side of the same range of hills. Some geologists, and particularly M. Humboldt, describe a formation of sandstone called *quader sandstein*, as being directly interposed between the lias and the oolites. Many English geologists regard this sandstone as identical with the iron-sand or Hastings-sand. According to Humboldt, quader sandstein has a whitish-yellowish or grayish colour; the grains are fine, and are united by an almost invisible argillaceous or siliceous cement; it contains but little mica, which is always of a silvery colour, and occurs in detached scales.—*Essai sur le Gisement des Roches*, p. 268. The quader sandstein placed between lias and oolite, corresponds in geological position with the sandy beds that separate these formations in Gloucestershire; but the quader sandstein described by other geologists as containing numerous vegetable fossil remains, may with much probability be referred to the iron-sand over the oolite, which will be described in the following chapter.

CHAPTER XIII.

ON CHALK, AND THE SUBJACENT STRATA CONTAINING REMAINS OF LAND PLANTS AND FRESH WATER ANIMALS.

Remarkable Zoological Characters of the Strata between the Upper Oolites and Green-sand.—Purbeck beds.—Iron-sand.—Tropical Plants and gigantic Animal Remains discovered in it.—Supposed appearance of the country at the period when these Animals flourished.—Green-sand.—Chalk-marle.—Lower Chalk.—Chalk with Flints.—Thickness and Extent of Chalk in various countries.—Inferences from the condition of the Fossils found in Chalk.—Observations on the State of the Upper Secondary Strata previous to the deposition of the Tertiary Strata.

In an elementary treatise on Geology, it is desirable to present to the view of the reader, not the geology of a single country, but that of the whole globe, as far as it has been ascertained. In certain countries, particular formations occupy a considerable extent, and are of great thickness; in other countries, similar formations are often wanting altogether, or the beds are so thin as scarcely to excite notice. The upper secondary strata cover more than one half of England, and hence the English geologist might be suspected of bestowing upon them too great a portion of his attention; but a more accurate examination of other countries, has fully proved, that many of the British strata which were formerly believed to be of very limited extent, are spread over a great part of Europe, and preserve the same order of succession as in our own island:—a description of these strata is therefore an essential part of general geology. The formations of the magnesian limestone, the red marle, the lias, the oolites, and the chalk, have risen into geological importance within the last twelve years; and the reproach cast upon South Britain by our neighbours on the other side of the Tweed, namely, "that there was little or nothing in England worth the attention of a geologist," has lost all its force. The beds of sand and clay, that intervene between the two last formations above enumerated, were however still more recently regarded as unworthy of particular notice, as it could not be expected, that beds of sand or clay should preserve the regularity of stony strata, over a great extent of surface: but the recent labours of Mr. Mantell and of Dr. Fitton, have made us acquainted with facts respecting these earthy and sandy deposits, which are scarcely exceeded in interest, by any discoveries in the lower strata.

In some of the lower formations we occasionally find indications of dry land and fresh-water having existed in the vicinity at the time when the strata were deposited; but we no where discover a single stratum, of which we can say decidedly,—this was once the dry surface of an island, or a continent. In the strata which we are now to describe, the shells belong chiefly if not exclusively, to species which are regarded as river shells; and the abundance of tree-ferns and other land plants indicate, that the strata in which they are found, were the soil on which they originally grew: this is rendered still more probable by the occurrence of the bones and teeth of herbivorous animals in the same strata. Some of these animals are of such a vast and appalling magnitude, as would exceed the sober measure of ordinary belief, if unsupported by the existence of well preserved parts of their skeletons, that leave no room for doubt.

The beds which preserve the remains of land plants, and of animals living partly or entirely on dry land, are covered by others of marine origin, and by the vast formation of chalk, in aggregate thickness not less than six hundred feet, but in which the remains of no land animal have as yet been discovered.

Between the upper oolites described in the last chapter, and the lowest part of the chalk formation, the following beds may be enumerated, commencing with the lowest.

The *Purbeck beds*, so called from the Isle of Purbeck in Dorsetshire, where they were formerly quarried for a limestone denominated Purbeck marble. These beds consist of argillaceous limestone, alternating with shale; the upper beds furnished the best stone: the total thickness of all the strata is about three hundred feet; they abound in fresh water shells.

* The *Iron-sand* or *Hastings-sand* covers the Purbeck beds; it is chiefly a siliceous sand or loose sandstone, containing the brown oxide of iron, which generally gives the sandy beds a reddish brown colour: beds of clay and fullers-earth are occasionally interstratified with the iron-sand.

The oxide of iron, so abundantly disseminated through this sand, is often concreted into hard nodules in irregular veins, which project above the surface, wherever steep banks or escarpments of iron-sand occur. Silicified wood and wood coal are found in various parts of the sandstone belonging to this formation, both in England and on the Continent. A very deep section has been cut through the iron-sand, at Woburn in Bedfordshire, to level the great road from London to Northampton: a distinct view of its mineral characters may there be observed; and in the vicinity of Woburn there are pits made in the sand, to extract fullers-earth. But in Tilgate Forest in Sussex, the zoological characters of this formation are most remarkably displayed. Mr. Mantell has published a very interesting account of the fossil remains which he discovered there. They consist of petrified trunks of large plants, bearing a resemblance to the palms, arborescent ferns, and gigantic reeds of tropical climates; the shells of fresh water genera, as the freshwater muscle, the mya, cyrena, paludina, and Helix vivipara. Some remains of fish, and three distinct species of turtles, have also been discovered; and the bones, teeth, and scales of at least four gigantic species of the lizard family; namely, the crocodile, plesiosaurus, megalosaurus, and iguanodon.

The crocodilian remains are pronounced by Cuvier to be, almost identical with those of the fossil crocodile discovered at Caen in Normandy, which belongs to the genus gavial (the crocodile of the Ganges.)

The Plesiosaurus.—This animal has been noticed, Chap. II. and X.

The Megalosaurus.—The bones of this animal found at Tilgate are similar to those discovered by Mr. Buckland in the Stonesfield strata. The megalosaurus is supposed to approach nearer to the form of the Monitor* than to any other species of living lizard; but its size is so enormous, that Cuvier says, if we suppose it to have possessed the proportion of the monitor, it must have exceeded seventy feet in length.

The Iguanodon.—A nondescript herbivorous reptile, which Cuvier pronounces to be the most extraordinary animal yet discovered. Its structure approaches nearest to that of the Iguana, a large species of lizard in the West Indies: its length was between sixty and seventy feet, which is double that of the largest living crocodile. But the great peculiarity of the iguanodon, is the form of its teeth, which bear a striking resemblance to the grinders of herbivorous mammalia, being evidently intended for mastication, in which respect it differs from all living animals of the lizard family. The herbivorous amphibiæ gnaw off the vegetable productions on which they feed, but do not chew them.—"Since the vegetable remains," says Mr. Mantell, "with which the teeth of the iguanodon are associated, consist principally of those tribes of plants that are furnished with rough thick stems, and which were probably the principal food of the original animal, we may be permitted to remark, that this peculiar structure of the teeth seems to have been required, to enable the animal to accommodate itself to the condition in which it was placed."—The iguanodon appears also to have possessed a horn, equal in size and not very different in form from the horn of the rhinoceros: in this respect, it resembles a living species of iguana, a native of St. Domingo.

Mr. Mantell concludes his "Illustrations of the Geology of Sussex," with the following interesting observations.

"We cannot leave this subject without offering a few general remarks on the probable condition of the country, through which the waters flowed that deposited the strata of Tilgate Forest; and on the nature of its animal and vegetable productions. Whether it were an island or a continent, may not be determined;

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* The Monitor—a species of lizards which are supposed to give warning of the approach of the crocodile by a hissing noise.

but that it was diversified by hill and valley, and enjoyed a climate of a higher temperature than any part of modern Europe, is more than probable. Several kinds of ferns appear to have constituted the immediate vegetable clothing of the soil; the elegant *Hymenopteris psilotoides*, which probably never attained a greater height than three or four feet, and the beautiful *Pecopteris reticulata*, of still lesser growth, being abundant every where. It is easy to conceive what would be the appearance of the valleys and plains covered with these plants, from that presented by modern tracts, where the common ferns so generally prevail. But the loftier vegetables were so entirely distinct from any that are now known to exist in European countries, that we seek in vain for any thing at all analogous without the tropics. The forests of *Clathrariæ* and *Endogenitæ*, (the plants of which, like some of the recent arborescent ferns, probably attained a height of thirty or forty feet,) must have borne a much greater resemblance to those of tropical regions, than to any that now occur in temperate climates. That the soil was of a sandy nature on the hills and less elevated parts of the country, and argillaceous in the plains and marshes, may be inferred from the vegetable remains, and from the nature of the substances in which they are enclosed. Sand and clay every where prevail in the Hastings strata; nor is it unworthy of remark, that the recent vegetables to which the fossil plants bear the greatest analogy, affect soils of this description. If we attempt to pourtray the animals of this ancient country, our description will posses more of the character of a romance, than of a legitimate deduction from established facts. Turtles, of various kinds, must have been seen on the banks of its rivers or lakes, and groups of enormous crocodiles basking in the fens and shallows."

"The gigantic *Megalosaurus*, and yet more gigantic *Iguanodon*, to whom the groves of palms and arborescent ferns would be mere beds of reeds, must have been of such prodigious magnitude, that the existing animal creation presents us with no fit objects of comparison. Imagine an animal of the lizard tribe, three or four times as large as the largest crocodile, having jaws, with teeth equal in size to the incisors of the rhinoceros, and crested with horns;—such a creature must have been the iguanodon! Nor were the inhabitants of the waters much less wonderful; witness the plesiosaurus, which only required wings to be a flying dragon; the fishes resembling *Siluri*, *Balistæ*, *&c.*"

The parts of England where the iron-sand covers a considerable extent of surface, are the counties of Kent, Sussex, and Bedfordshire. In France it is denominated *gres ferrugineux.*

The *Weald-clay*, so called from being first noticed in the Wealds of Kent, varies in its quality from a dark tenacious clay, to a gray calcareous marle. Some of the beds consist of argillaceous limestone, filled with univalve shells of the genus Vivipara, a freshwater shell. This limestone, called Petworth or Sussex marble, closely resembles the Purbeck marble before described. In Kent, the Weald-clay is three hundred feet thick, but it does not appear to be an extensive bed, as it grows thinner in the adjacent counties, and has not been traced beyond them. Here terminates the freshwater formation below chalk, comprising the Purbeck beds, the Hastings or iron-sands, and the Weald-clay, with their associated beds of marle and limestone. Whether the whole series were deposited in a freshwater lake, or whether the remains of freshwater plants and animals were carried down by rivers, and left in estuaries at their mouths, perhaps future investigation may determine. Whatever was the condition of this part of the globe, when the strata with freshwater remains were formed, we have certain proof, that it was again covered by a very deep sea, in which all the thick beds of chalk and chalk marle were deposited, and in which the numerous tribes of marine animals lived and flourished, that have left their exuviæ in the different parts of that great calcareous formation.

Green-sand.—This bed, which is of considerable thickness, is interposed between the Weald-clay and the chalk, and is to be distinguished from the iron-sand below both, by its mineral and zoological characters.* The green-sand might perhaps be propearly classed as a lower member of the chalk formation, as it accompanies chalk, both in England and on the continent of Europe; and the lower beds of chalk or chalk marle, pass gradually into the green-sand, by a close intermixture with it, and have, on account of their greenish or yellowish colour, been denominated *Glaucenie crayeuse* and *Craie chloritée*, by the French.

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* The fossils in the Weald-clay of Tilgate Forest, according to Mr. Mantell, are the Cypris faba, Paludinæ, Cyrenæ, scales of fishes, and Viviparæ paludinæ.

Green-sand has received its English name from its intermixture with particles of green earth; it is very variable in its mineral characters, being sometimes found composed of loose siliceous sand; in other situations, it forms sandstone cemented by calcareous earth; it abounds in siliceous concretions, which vary from an opaque bluish white chert or hornstone, to flint and chalcedony. The geodes found in the green-sand near Sidmouth, are composed of opaque chert on the outside, and contain within, mammillated concretions of beautiful chalcedony, and occasionally perfect minute rock crystals. Some of the sandy concretions near Sidmouth have a beautiful green colour, which I found to proceed from green sulphate of iron.*

The fossils in the green-sand are very numerous and in high preservation: they consist chiefly of various species of chambered and unchambered univalve shells, and of bivalve shells and echini; few remains of vertebrated animals have been found in any part of the beds. Amidst the great variety of fossil species, it would be difficult to select any one which is decidedly characteristic of this formation; but where several species are associated in the green-sand in different situations, they may serve collectively to identify it in remote countries. M. A. Brongniart has thus attempted to identify the strata near the Perte de Rhone on the confines of Savoy, with the green-sand or chalk marle in the north of France and in England, in an interesting memoir entitled *Sur les Caractères Zoologiques des Formations*, publ. 1822.†

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* On the east of Sidmouth, immediately above the town, I observed green-sand intermixed with black particles, which I ascertained to be the black oxide of manganese.

† Near the Perte de Rhone, in the bed of the river Valteline, I discovered strata bearing a great resemblance to the lower English chalk.

There is one negative character which the fossils in the green-sand afford; the echini of the genus Spatangus, which are common in chalk, and in the green-sand, have not been discovered in any lower formation. In the western part of England, the fossils in green-sand are often converted into chalcedony. Below the green-sand, in the county of Sussex, there is a stratum of clay, called *galt*, under which there is a ferruginous sand, passing in the lower part into green-sand; this is sometimes called Shanklin-sand, and sometimes the lower green-sand. According to Mr. Mantell, it contains casts of the trigoniæ, patellæ, modiolæ, &c. The galt or Folkstone marle, contains belemnites, ammonites, and nautilites, with remains of fishes and crabs.

The green-sand formation is covered by chalk; but in some parts of England it extends beyond the chalk, and covers the subjacent strata at a considerable distance from the chalk formation. The French chemist M. Berthier, discovered that the green particles in the strata under and over chalk, are the silicate of iron. The general name given by the French to the green-sand formation, is *gres et sables verts.*

Chalk.—This rock extends through many of the eastern and southern counties in England; it may be traced with little interruption from Yorkshire into Kent, and from Kent into Dorsetshire. Chalk is a stone so well known in England, as to require but little description. Its prevailing colour is white, but some of the lower beds incline to gray; it has an earthy texture, and is generally so soft as to yield to the nail, though some of the lower beds are sufficiently hard to be employed for building-stone. The average thickness of the chalk strata may be estimated at from six hundred to eight hundred feet. The upper beds contain numerous nodules and short irregular veins of flint; the lower chalk contains fewer flints, and is generally hard: below this, there occur beds of soft chalk, called chalk marle. In France the beds of chalk seldom attain the thickness which they have in England. The French divide the chalk formation into the lowest or chalk marle, with green particles, *craie chloritée*, or *glauconie crayeuse;* the middle or coarse chalk is of a grayish colour and intermixed with sand; it contains whitish chert (*craie grossière* or *craie tufeau;*) the upper or white chalk (*craie blanche*,) which contains nodules of common flint.

M. Humboldt, after noticing the great intermixture of the sandy calcareous and argillaceous beds, in the formations below chalk, and which is greatly increased in the tertiary strata above chalk, observes, "that nature seems to have relented in her tendency to form complex mixtures when chalk was deposited." In the chalk formation, we find an assemblage of calcareous strata, composed of carbonate of lime, with very little intermixture of the other earths, and without any alternation with argillaceous or siliceous strata. Chalk is not, however, absolutely pure; for beside the nodules and veins of flint that occur in it, but which bear no sensible proportion to the whole mass, some of the strata contain an intermixture with siliceous sand, and in other strata, calcareous earth is combined with magnesia. In some of the chalk strata in France, the magnesia exceeds ten per cent, and I believe many of the English chalk strata contain as great a proportion of magnesian earth.

Chalk which contains a notable portion of magnesia, may generally be known by an appearance of dendritical spotted delineations on the surface of the natural partings, and by minute black spots, like grains of gunpowder, in the substance of the chalk.

The stratification of chalk is seldom so distinct as in many other calcareous formations: this may be partly owing to the softness of the beds, which appear to have yielded to pressure; and to the same cause we may probably ascribe the fractured state of the nodules of flint in chalk, which often appear whole, when they are imbedded in the rock, but when taken out, are found to be shivered into innumerable angular fragments. The nodules of flint, are commonly arranged in pretty regular layers in the chalk; they occur in detached concretions of various shapes and sizes: some of them are believed to be the casts of spongiform zoophytes; and this is rendered more probable, by the frequent occurrence of fossil echini in chalk, in which the internal part is filled with flint, and forms a perfect cast of the animal.

The constant occurrence of flint in the upper chalk, and the apparent conversion of animal remains into flint, has formerly given rise to much speculation respecting the origin of flint. and it was at one time maintained, that flint and chalk are convertible or capable of undergoing a mutual transmutation: but whatever hidden processes there may be in the great laboratory of the earth, by which all mineral substances, held to be elementary by the chemist, may be resolved into original elements still more simple, and afterwards recompounded into other substances, we have no reason to mount so high in our speculations, respecting the origin of flint.

Flint is siliceous earth nearly pure, and we find the same earth under different forms combined with almost all calcareous rocks in a greater or lesser proportion.

Primitive limestone is often much intermixed with siliceous earth. Transition limestone occasionally contains rock-crystals imbedded in the mass: this is not unfrequently the case in some of the transition limestones of Derbyshire. The magnesian limestones and oolites, are also very commonly intermixed with siliceous grains, and often alternate with strata that are more or less siliceous: hence we need not be surprised to find siliceous earth in chalk, either combined with calcareous earth, or separated in distinct concretions. When the cavities of a sponge or crustaceous animal admitted the siliceous earth to enter, it appears to have been infiltered from the chalk, in the same manner as the nodules of chalcedony have been infiltered into the cavities of lava or basalt. Between chalcedony and flint there is a near resemblance, they are only different modes of the same substance, and the flint nodules in the western counties of England, are frequently chalcedonic. The hardest rocks and stones are permeable to water; and flint when first got out of the chalk is easily fractured, and the fractured surface is found covered with moisture.

The fossils found in chalk are the remains of marine animals. The Echini, of which there are various species, are so numerous that they are considered as characteristic of this formation, and some are peculiar to it, particularly the helmet-shaped echinus (*ananchytes.*)

Ammonites of a different species from those in the lower strata are occasionally found in chalk, and also belemnites and scaphites. There are but few spiral univalve shells in this formation, which perhaps may confirm the opinion before stated, that the animals of this class were not the inhabitants of deep seas. Of bivalve shells there are many species; and the remains of zoophytes, particularly of sponges and alcyonia, are numerous.

The remains of vertebrated animals are rare; they consist chiefly of the teeth, palates, vertebræ, and scales of fishes. The great preservation in which some of the most delicate of these remains are frequently found, renders it probable, that chalk was deposited in a deep and tranquil sea. Balls of iron pyrites with a radiated diverging structure, are frequently found in chalk; and the large spines of echini, of the genus Cidaris, are found converted into pyrites in the chalk-pits near Dorking; they resemble small fungi with a stalk and rounded head.

All the fossils in chalk are regarded as belonging to species now extinct, and several of them belong to extinct genera. Mr. Parkinson says that "hardly a single fossil has been found in the lower chalk, which has been met with in the upper or in any other stratum." Chalk extends along the northern coast of France opposite the chalk cliffs of England, of which it was no doubt a continuous formation: it extends also far into the interior of France, and may be traced through the Netherlands and part of Germany, into Poland, and to the Island of Rugen in the Baltic, and into Sweden.

The lower part of the chalk formation may also be traced to the calcareous ranges of the Alps. We have no precise information respecting the extent of chalk in Asia: it has been said, but with what truth I know not, that Jerusalem is built upon chalk. Humboldt discovered no chalk in South America, nor has it been hitherto found in any part of the United States. Chalk is the uppermost of the strata classed as secondary; it was till very lately regarded as the most recent of rock-formations, except the volcanic.

Between the epoch when chalk was deposited, and the period when it was covered with the tertiary strata, there appears to have been a considerable interval, during which the surface of the extensive mass of chalk, was in many situations, deeply furrowed, and excavated into valleys and basins, before a new series of strata were deposited upon it, destined to support a new creation of animals of a superior class, altogether different from those which have left their remains in the subjacent strata.

CHAPTER XIV.

ON THE TERTIARY FORMATIONS.

On the Formation of the Tertiary Strata in Lakes or inland Seas.—On their subsequent destruction by external causes.—On the discovery of the Tertiary Strata of France.—Alternations of Marine and Freshwater Strata.—General Classification of Tertiary Strata.—Lower Marine Strata sometimes alternating with Beds containing River Shells and Lignite.—Lower Freshwater Strata sometimes containing Marine Shells.—Upper Marine Sandstone.—Upper Freshwater Limestone. —Plastic Clay and London Clay.—Molasse.—On the Remains of Land Quadrupeds supposed to be found in Molasse.—On the London Clay in the Vale of Thames and the Strata with pure Water below it.—*Calcaire grossier* and *Calcaire siliceux*.—Gypseous Marle and Gypsum of Paris containing Bones of numerous extinct Species of Land Quadrupeds.—Upper Marine Sandstone of France and England.—Freshwater Limestone of Paris and the South of France.—Remarkable position of the Tertiary Strata in the Isle of Wight.—Opinions respecting the alternation of Marine and Freshwater Formations.

The tertiary formations comprise all the various regular beds of limestone, clay, marle, sandstone, or sand, that have been deposited after chalk.—They were until very recently confounded with alluvial and diluvial deposits, and were scarcely noticed by geologists. It is now however discovered, that the tertiary formations are very widely spread over the present islands and continents, and are of considerable thickness.

The most remarkable discovery that has been made respecting the tertiary deposits is, that many of them contain the bones of mammiferous quadrupeds, as perfect in their organization as any of the existing species of land quadrupeds, but most of them belonging to genera or species that are extinct. The tertiary strata are further remarkable, for presenting the frequent alternation of beds containing the remains of marine animals, with other beds that contain the bones of land animals, or freshwater shells. It appears that the tertiary strata were chiefly formed in detached inland seas, or lakes; hence there is a considerable diversity in the thickness, number and quality of the beds, in different districts or countries.

During the deposition and consolidation of the upper secondary strata, the crust of the globe appears to have remained in a quiescent state, and to have experienced few violent concussions and derangements from internal causes. Those faults and dykes which have bent, contorted, or broken the lower strata, rarely extend to the upper secondary strata; for we find the latter arranged horizontally over them, or dipping with a very slight degree of inclination. Where the upper secondary strata have experienced any considerable disturbing force, it appears to have operated at a comparatively recent period, after the deposition of the tertiary strata; for they are frequently raised or depressed together, as we have before noticed in the Alps.

In our own island, we have instances of partial subsidences of the upper secondary and tertiary strata, which however are few and of very limited extent.

Though in England and the northern parts of Europe, few internal disturbing causes have acted intensely or extensively on the crust of the globe, after the deposition of the upper secondary, and the tertiary strata, we have clear indications of an external force, which has torn away considerable portions of them, and transported their ruins into distant countries, or into the ocean. Many of these strata have evidently once extended beyond their present limits; and some of the tertiary strata have been so completely destroyed in many situations, that we can only infer their former existence, by a few remaining detached portions.

In France, the tertiary strata are more widely spread, and many of them more fully developed, than in England: it is indeed scarcely possible to imagine a more distinct display of the series of strata in any class of rocks, than is presented close to the very gates of Paris. In a capital so distinguished for scientific investigation, and possessing so many able and acute observers, it does indeed seem truly extraordinary, that the strata with which they were surrounded, should never have been properly examined until so recent a period, as the early part of the present century. What is daily before our eyes seldom excites attention, or is deemed deserving of much notice; but there was another cause which long prevented the philosophers of Paris from observing the remarkable objects around them. Captivated with the generalizations of Werner, who it was firmly believed had unlocked all the hidden mysteries of Geology, and comprised in his system all the different formations that composed the crust of the globe, they saw before them a series of strata which had no agreement with any part of the Wernerian classification; hence they could not avoid the painful persuasion, either that the system of Werner was incomplete, or that they were unable to apply it properly. To avoid an acknowledgment so little satisfactory, the geologists of Paris averted their attention and that of their pupils from nearer objects, and directed them to the mountains of Germany or Switzerland. Had not another science, comparative anatomy, come to the aid of geology, we might yet have remained unacquainted with the tertiary strata around Paris. At length, the number of skeletons of strange and unknown animals discovered in some of the strata, forcibly attracted the notice of that distinguished naturalist, Cuvier, and it was resolved to investigate attentively the geology of the whole district. M. A. Brongniart was associated with Cuvier in the investigation, and in 1811 the result of their labours and observations was given in a work entitled *Essai sur la Géographie Minéralogique des Environs de Paris*,—the most luminous and interesting exposition of local geology ever presented to the world; and from this period we may date the first accurate knowledge of the tertiary strata.

The following extract from the Essay of Messrs. Cuvier and Brongniart, presents a general view of the arrangement of the strata round Paris.

"The country in which the capital of France is situated is perhaps the most remarkable that has yet been observed, both from the succession of different soils of which it is formed, and from the extraordinary organic remains which it contains. Millions of marine shells, which alternate regularly with fresh-water shells, compose the principal mass. Bones of land animals, of which the genera are entirely unknown, are found in certain parts; other bones remarkable for their vast size, and of which some of similar genera (*quelques congenères*) exist only in distant countries, are found scattered in the upper beds. A marked character of a great irruption from the south-east is impressed on the summits, (*caps*,) and in the direction of the principal hills. In one word, no country can afford more instruction respecting the last revolutions which have terminated the formation of the present continents."

Though chalk is the foundation rock of the country for a considerable extent round Paris, it rises to the surface only in a few situations, being covered by the other strata in the following order, beginning with the lowest stratum above chalk.

1. Plastic Clay and Lower Sand.
2. Calcaire grossier.
3. Calcaire siliceux and Sandstone.
4. Gypseous Marle.
   Gypsum with Bones.
   Upper Gypseous Marle.
5. Sandstone and Sand without Shells.
   Upper Marine Sandstone.
   Millstone without Shells.
6. Fresh-water Limestone, including Marles, and Millstone, with fresh-water Shells.
7. Alluvial Soil, ancient and modern, including Pebbles, Pudding-stone, Black Earth, (*les marnes argilleuses noires*,) and Peat.

The total thickness of the different beds and strata over the chalk, as given in an ideal section of the country, is nearly five hundred feet.

Each of the above divisions in the tertiary strata in the Paris basin, admits of numerous subdivisions; but it is not the object of the present volume to enter into the minute details of local geology, but to present a view of the principal formations that occur in various countries. Many of the beds in the Paris basin are not found elsewhere, and therefore cannot be taken as types of the whole class; and the lower bed called the plastic clay, is but very imperfectly developed near Paris. In attempting to generalize the tertiary formations, a difficulty presents itself, if we are to class them by their zoological characters; for some of the formations, which contain exclusively the remains of marine animals in certain situations, contain in other situations river or lake shells, with wood and the bones of land animals. It is therefore probable, that while the waters in one lake or basin might be saline, those in another lake might be fresh; and two cotemporaneous formations may hence contain very different organic remains.

The tertiary formations may be conveniently divided as under:

Tertiary Formations.

1. Lower Marine Beds. — Sometimes intermixed with fresh-water beds.
    - *a* Argillaceous and Sandy deposits, Plastic Clay, Sand, London Clay, — *Argile et Gres tertiaires à lignites.*
    - *b* Lower Marine Limestone.—*Calcaire grossier.*
2. Lower Fresh-Water Beds. — Sometimes intermixed with Marine.
    - *a* Marle.
    - *b* Gypsum.
3. Upper Marine Formation.
    - *a* Sand and Sandstone without Shells.
    - *b* Sandstone with Shells.
4. Upper Fresh-Water Formation.
    - *a* Limestone.
    - *b* Siliceous Mill-Stone.

The plastic clay, and London clay, with the various associated beds of sand, may properly be regarded as one formation, of which the plastic clay is the lowest member resting on chalk. Near Paris this is a very thin bed, but in the south of France it acquires a great degree of thickness, and appears to comprise the upper argillaceous beds, or what we call the London clay: it is remarkable for the vegetable fossils and beds of lignite which it frequently but not invariably contains. In England, in the lower beds of this formation, there are found beds of imperfect wood coal; but both the plastic clay, and the London clay, contain shells and other remains of marine animals; whereas on the Continent, beside the great quantities of fossil wood and wood coal found in the same argillaceous beds, there are numerous remains of fresh water shells, which render their title to be denominated marine formations more than doubtful. The beds of sand are sometimes of considerable thickness. By many geologists it is maintained, that the beds of soft sandstone, (called *molasse*,) and of sandstone conglomerate, (called *nagel flue* in Switzerland,) belong to this part of the tertiary formations. That some of these beds may be tertiary I will not deny; but I am fully convinced, that many beds of molasse in Savoy are covered by the Jura limestone and oolites, having repeatedly seen them in contact, and got specimens from each bed at the line of junction.*

The bones of horses, with the tooth of an elephant, have been found in a bed of unctuous clay near Margate; but as the clay is superficial, it may be a diluvial formation.

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* As the opinions of geologists have been much divided respecting the molasse, or soft sandstone of Switzerland and Savoy, I shall here insert some observations upon it, given in the first volume of my Travels in the Tarentaise. I must first remark, that almost all the sandstone strata in these countries possess nearly the same character of minute angular fragments cemented by calcareous earth; and if the term molasse be applied to all of them, molasse is of very different ages, like the sandstone in the English strata. In the chapter on the destruction of rocks, I shall advert to the strata of molasse again; they have hitherto received much less attention than their magnitude and importance, as constituent parts of the outer ranges of the Alps, require.

"The outer calcareous mountains on the western side of Savoy, all rest upon an immense formation of soft sandstone, (molasse,) and are interstratified with it; and so far from this sandstone being more recent than the limestone, (as Saussure supposed,) it constitutes a considerable part of the bulk of these mountains, that are called calcareous. In the Valley of les Echelles, the immediate junction of the limestone with the sandstone may be seen soon after entering the valley from the archway. This vast wall of limestone, nearly one thousand feet in thickness, rests upon a mass of sandstone of unknown depth: there is very little dip where the first junction is seen, but about a mile below, you meet with the limestone again in conjunction with the sandstone, and thrown into a vertical position. The workmen that I met with near the mouth of the gallery, said they always found sandstone below the limestone, and they considered it as the lowest bed in the country: but this is obviously a mistake. The sandstone, or molasse, on which the limestone in this

If the sandstone with lignite at Alpnach, near the lake of Zurich, really belong to this tertiary formation, we may cite it as containing the teeth and bones of the mastodon and other mammiferous quadrupeds, at the depth of two hundred and seventy feet.

But we have yet no decisive proof, that the lignite of Alpnach does not belong to the oolitic series, as the beds of limestone over it, resemble the Jura limestone: should this ultimately prove to be the fact, we should have another instance, like that of Stonesfield, of the bones of mammiferous animals occurring in strata below chalk.*

In France near d'Auteuil and south of the Dordogne, according to Humboldt, bones of vertebrated land animals are found in a formation resting on chalk, analogous to the plastic clay. Baron Cuvier says, however, that he has not discovered the bones of land quadrupeds in any strata below the *calcaire grossier* which covers the plastic clay. But neither the plastic clay nor

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part of Savoy reposes, or which is subordinate to the limestone, is composed of smallish grains of quartz or chlorite, pretty equally mixed. In the sandstone of les Echelles, which I got from its junction with the limestone, there were some particles of of rose quartz and mica. It scratched glass strongly when rubbed upon it; but when put into a dilute muriatic acid, it effervesced violently, and became friable, owing to the solution of the calcareous cement by which it appears, from this experiment, to be agglutinated. The molasse, which is interstratified with limestone and associated with coal on the lake of Annecy, also effervesced; but the particles being smaller, it appeared nearly homogeneous when examined without a lens. It has been recently stated, that the molasse of the Alps belongs to the same formation as the sandstone above chalk near Paris. There may be sandstone of that formation in the canton of Berne; but the molasse or sandstone in this part of Savoy, I am well convinced, is a member of formations that are lower than chalk. It is possible, however, that beds of this molasse may have been worn down during the great destruction of the strata, that has evidently taken place since they were deposited, and from the debris of this sandstone, upper beds may have been formed covering strata that are above chalk. The molasse which covers the bones and teeth of the mastodon and other large mammalia near Alpnach, nearly resembles that in this part of Savoy; but the particles are smaller, and more intimately mixed."—P. 176.

* Specimens of the strata above the coal of Alpnach were presented me by Professor Meissner of Berne, and are described in the 2d volume of my Travels, p. 167.

the gypsum beds of Paris, can be taken as types of the tertiary strata in other countries.

The London clay is placed over the plastic clay and sand, and is in fact an upper member of the great arenaceous and argillaceous formation, that covers chalk. Some geologists attempt to identify the London clay with the beds of calcaire grossier, and of gypsum, in the Paris basin, but their mineral characters are essentially different. The London clay is composed of dark blue or brown argillaceous beds, suitable for brick earth; and the small quantity of calcareous earth or of selenite that sometimes occurs in it, no more identifies it with the light limestone strata of the calcaire grossier, or the thick beds of gypsum in the Paris basin, than the wooden doors with iron nails of St. Paul's cathedral, would identify the stone of that building, with the wood in the shipping in the Thames. By attempting to unite things essentially different, in order to force an agreement with artificial classifications, we mystify what is clear and simple, and retard the progress of knowledge.

The uppermost bed of the London clay is of a reddish brown colour, and is more arenaceous than the lower beds; the colour of the lower beds varies from a bluish lead colour, to a blackish brown; they are often considerably indurated, and have somewhat of a slaty structure. The thickness of the London clay varies from one hundred to four hundred feet or more; this variable thickness is occasioned by the upper beds which form the surface of the land in the Vale of Thames, having been more excavated in some parts than in others.

As the London clay and plastic clay and sand, taken together, equal or exceed in thickness the beds of plastic clay, calcaire grossier, and gypsum in the Paris basin, the London clay may properly be regarded not as identical with the calcaire grossier and gypsum, but as their geological equivalent. While the beds of limestone and gypsum were depositing in the Paris basin, the London clay might be deposited in the London basin; and this may explain why many species of marine shells in the London clay, are similar to those found in the calcaire grossier: but we no where discover the astonishing variety of species, that occur in some of the strata of the calcaire grossier; nor have any bones of land quadrupeds, similar to those in the Paris basin, been found in the London clay. The two sides of the trough or basin in which the London clay and plastic clay were deposited, are formed on the north, by the range of chalk hills in Hertfordshire and the adjacent counties, and on the south, by the range of chalk hills in Surrey and Kent.

The relative geological position of the chalk, the plastic clay and sand, immediately upon it, and the upper bed of London clay covering the Vale of Thames, is represented in a small section at the bottom of the Map of England. Plate 5. In some parts of the Vale of Thames, as at Hampstead north of London, and near Cobham in Surrey, the London clay rises into hills three hundred feet above the Vale of Thames, and is capped by a bed of sand, which has received the name of the upper marine sand. *a. a.* chalk, *b. b.* plastic clay, *c. c.* London clay, *d. d.* marine sandstone. From this small section, the geological student may form some idea of the devastating effects of mighty inundations, which have swept over the surface of the globe, and carried away considerable portions of the upper beds. The marine sandstone *d. d.* which forms isolated caps on several of the hills in the Vale of Thames, was doubtless part of one continuous bed which has been excavated with a portion of the subjacent London clay; such excavations and denudations, are common phenomena in almost every country.

Balls of imperfect ironstone, (called *septaria*,) of which Parker's cement is made, are common in some parts of the London clay; branches and stems of trees, penetrated by the *Teredo navalis*, are found in it, and a species of resin, to which the name of *retinasphaltum* was given by Mr. Hatchett. Remains of turtles and crocodiles have been dug out of this clay at Highgate and Islington. The teeth and tusks of elephants have been discovered in many situations, in what is supposed to have been London clay, but which may have been a covering of diluvial clay, for the patches of diluvial gravel that are spread over many parts of the Vale of Thames, frequently contain the remains of elephants.* Ammonites and belemnites, and many genera of testaceous animals, that have left their remains in chalk and the lower strata, appear to have been extinct before the deposition of the London clay. Nautilites are however found in it, similar to the species inhabiting the Indian Ocean, and bivalve and univalve shells are so numerous, that it would be difficult to select any particular species, as peculiarly characteristic of this formation. The shells mostly belong to genera inhabiting our present seas; yet slight variations of form may sometimes be perceived, which have induced naturalists to regard them as distinct from living species. We should however bear in mind, that we know little or nothing respecting the habits of testaceous animals, or the changes produced in the shell, by difference of age or situation; therefore to pronounce that shells are of different species, from those in the present seas, on account of some slight variation of form, is scarcely more wise, than it would be to class individual men as different species, on account of the different forms of their noses. Cabinet philosophers however, who, except for a few weeks in summer, rarely travel beyond their museums, may sometimes attach more importance to the minute difference of form in a fossil shell, than to the structure of a range of mountains.

The springs that rise in the London clay, are generally impregnated with sulphate of iron and sulphate of lime, and some of the springs contain sulphate of magnesia; the quality of the water, however, varies much in different situations, and at different depths. To obtain soft water, it is necessary to bore or sink through the London clay to the sand above the chalk, and sometimes into the chalk itself.† The London clay, and the under beds have been perforated to the depth of three or four hundred feet in some situations, before good water could be obtained; when the stratum is pierced which holds the best water, it rises almost immediately, and sometimes overflows the surface. This admits of an easy explanation by referring to the section of the Vale of Thames. Plate 5. The water which enters the edges of the porous strata, say at *x. x.* descends to the lowest part of the trough or basin, and when perforated would rise to near the level of *x. x.* were the strata deposited in a basin, the edges of which rose on each side from the bottom of the Vale of Thames; but the strata are deposited in a longitudinal trough between the chalk hills of Hertfordshire and Surrey, so that the river Thames cuts through the porous edges of the strata below Greenwich, and the water being there let out, it can seldom rise much above the high water mark. Were it not for this, we might have natural *jets d'eau* of considerable height and magnitude in all the squares of London, to cool and refresh the air during the summer months, and supply the inhabitants in the vicinity with salubrious water. In order to preserve the water pure, that is obtained from chalk or the sand over chalk, it is necessary to line the inside of wells, or to put down tubes, to prevent the water from the London clay, intermixing with the pure water from below.

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* In clearing away the bed of gravel on the north side of the Regent's Park, the tusks of elephants were found, but in a mouldering state, in 1818.

† At the village of Wilsden, three miles north-west of London, the boring for water was made two hundred and eighty feet into the clay, and seventy-five feet below it into the chalk, when the water immediately rose to within thirty-five feet of the surface. Chalk rocks, and other calcareous rocks in which the strata are divided by fissures that are not filled with clay, always contain water in the fissures

Le calcaire grossier, or coarse limestone of Paris, is deposited upon the plastic clay, as the latter is upon the subjacent chalk: between the plastic clay, however, and the *calcaire grossier*, there is a bed of sand, but geologists are not determined, to which of the two formations it belongs. The *calcaire grossier* differs in its quality in the different beds, but it may be described generally as a yellowish earthy limestone, which bears some resemblance to Portland stone in its fracture, texture, and colour;

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when the strata dip under the surface of the ground, or when they are covered by argillaceous beds. This is also the case with coal strata, and the presence of water is necessary to keep the coal in good condition. If the water be entirely drained from a bed of coal a considerable time before it is worked, the quality of the coal is much deteriorated. This may be occasioned, by air penetrating the fissures and promoting the decomposition of pyrites in the coal.

but it is not oolitic. The strata of limestone alternate with argillaceous marle and shale, and with calcareous marle.

The lowest bed of *calcaire grossier* is soft, and much intermixed with green particles and sand; it contains a great number of the fossils, called nummulites, on account of their being flat and round, and resembling in shape a small coin. The shells in this bed are in high preservation. In the beds immediately above, called the middle beds, there are a prodigious number of marine shells, and also the stems and impressions of leaves of plants, that are not marine. In the lowest and middle beds of the *calcaire grossier*, no less than six hundred different species of shells are found.

In the upper part of the *calcaire grossier*, the strata are several feet thick, and yield a hard coarse grained and durable limestone; it is from these strata that the best building-stone it procured. It is often nearly filled with shells of the genus *cerithium*, and has hence been sometimes called *calcaire à cerites*.

Between the strata of building-stone there often occur thin strata of flint or chert; in some parts these siliceous strata enlarge into thick beds of chert (*silex corné*) or into beds of sandstone containing marine shells; in the beds of this sandstone at Pierrelaie, freshwater shells have been discovered, mixed with numerous marine shells. The total thickness of the beds of *calcaire groissier* near Paris, is about ninety feet.

No beds of limestone resembling the *calcaire grossier* of Paris, are found in the tertiary strata of England. The *calcaire grossier* in the departments of La Dordogne and La Gironde and other parts of France, presents a considerable difference from that in the Paris basin. In Hungary, extensive strata of the *calcaire grossier* have been described by M. Beudant; they are in every respect analogous to the strata in the Paris basin, both in their mineral and zoological characters. The lower beds also are intermixed with shelly sand, and green particles, which bear a close resemblance to the shelly depositions in the plain of Lombardy. M. Humboldt thinks he discovered a formation similar to the *calcaire grossier* in some parts of South America.

Calcaire siliceux is composed of limestone, sometimes gray and compact, and sometimes tender and white: it is penetrated by silex in every direction, and in all its parts; according to M. Brongniart, the *calcaire siliceux* occupies the place of the *calcaire grossier;* others regard it as an upper formation. Some of the beds of the *calcaire siliceux* furnish mill-stones, and contain river shells. In this bed, the siliciate of magnesia was discovered by M. Brongniart. The siliceous infiltrations sometimes forms plates of chalcedony and mammillated concretions of chalcedonic chert, coloured red, violet, and brown.

Gypseous Marle and *Gypsum.*—This remarkable formation occurs in detached hills along the course of the rivers Marne and the Seine; it is supposed to have originally extended as one continuous bed from east to west, twenty-five leagues in length and eight in breadth; its greatest thickness is about two hundred feet.

The gypsum formation consists of alternating beds of gypsum and argillaceous and calcareous marle, which are regularly arranged, and preserve the same order of succession wherever they have been examined. The gypsum forms three distinct masses. The lowest consists of thin strata of gypsum containing crystals of selenite, which alternate with strata of solid calcareous marle, and with argillaceous shale. The middle is like the lowest mass, except that the strata of gypsum are thicker, and the beds of marle are not so numerous; it is chiefly in this mass that fossil fish are found. The uppermost mass is the most remarkable and important of all, it is in some parts more than seventy feet thick; there are but few beds of marle in it; the lower strata in this mass have a prismatic or columnar structure: the gypsum is pure and finely granular; it has a light yellowish brown colour, which might perhaps more properly be called a dirty white. In this upper mass of gypsum the skeletons and scattered bones of birds and unknown quadrupeds are discovered; sometimes they are found in the solid gypsum, and sometimes in the marle that separates the beds. Remains of turtles and crocodiles have also been found in the same strata. It is to the indefatigable and enlightened labours of Baron Cuvier that we are indebted for a knowledge of the different genera of remarkable land quadrupeds, belonging to a former world, found in the gypsum quarries; they differ from any genera of living animals. These land quadrupeds were herbivorous, they belong to the order which Cuvier has denominated *Pachydermata* or thick-skinned non-ruminant animals. One of the genera called *Palæotherium* (or ancient animal,) appears to bear some relation to the rhinoceros, the hippopotamus, and horse, and in some respects to the pig and the camel.

Of this genus there are eleven or twelve species; five of them have been found in the Paris gypsum. The largest was of the size of a horse, but its form was heavy, and its legs thick and short; its grinders resemble those of the rhinoceros, and the daman;* it had six incisive, and two canine teeth like the tapir, and like that animal, had a short fleshy trunk: it had three toes on each foot, and is supposed to have inhabited marshy ground, and to have lived on the roots and stems of succulent marsh plants. One of the species, however, possessed the size and the light figure of the antelope, and is supposed to have browsed on aromatic plants, or the buds of young trees in dry situations, like other light herbivorous animals. Probably, says Cuvier, it was a timid animal with large moveable ears like those of the deer, which could apprise it of the least danger: doubtless its skin was covered with short hair; and we only want to know its colour, in order to paint it as it formerly lived in the country, where, after so many ages, its bones have been dug up.

One species of the *palæotherium* was not larger than a hare.

The *Anoplotherium*, or animal without defensive teeth, has been found only in the gypsum quarries near Paris. It has two very distinctive characters: the feet have only two toes, which are separated the whole length of the foot; the teeth, of which there are six incisive in each jaw, a canine tooth of the same height, and six molares or grinders, all form a continued series without any interval, which is the case with no other known quadruped.

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* An African quadruped, the size of a rabbit, but closely resembling the rhinoceros.

The most common species is of the height of a boar, but much longer. There are remains of other animals, in the same quarries, allied to the anoplotherium, but which differ in the form of their teeth. The bones of six species of birds have been discovered in these quarries, and also the remains of a few carnivorous animals allied to the dog and the weasel. It is remarkable, that in the middle of the gypsum formation, and throughout the greater part of it, we find the remains of land animals and of freshwater fish and shells; but near its upper and lower limits, both in the gypsum and the marle, the fossils are those of marine animals. A bed of green marle, which may be very distinctly traced near the termination of the upper mass of gypsum, separates the freshwater from the sea shells; and in the lower part of the gypsum formation, marine shells are found in the gypsum itself.

It may be useful to those strangers who visit Montmartre for the first time, to state, that this thin green bed, which can be distinctly seen and traced, may serve them as a key to the geology of the place; as it separates all the lower marine and freshwater formations from the upper.

The gypsum of the Paris basin was probably deposited in an extensive lake, on the borders of which the land animals, whose remains are discovered in it, flourished and perished. Some of them appear to be formed for swimming or living much in the water, like the otter or water-rat. Whether the water in this lake was salt or fresh is by no means certain, though M. Brongniart thinks that a single freshwater shell found in the gypsum would decide the question: but this opinion, however high the authority of so distinguished a naturalist and geologist may be, cannot I conceive be maintained; for in some of the beds, we meet with a mixture of marine and freshwater shells,—and in this case who shall determine, whether such beds are of marine or freshwater origin? The intermixture of shells clearly shows, that they have been transported from their native situations, or that marine and freshwater moluscæ may live in the same estuary or lake, if the water be brackish, which is confirmed by recent observations and experiments.

The fossil bones found in the gypsum quarries near Paris, are light and porous, and appear to have been scarcely penetrated by gypsum: this is very remarkable; for if we suppose the gypsum to have been held in solution by water, like the sulphate of lime in recent springs, it seems extraordinary that it should not have penetrated into the pores of the bones. I am not aware that the circumstance has before been noticed by geologists, but I think the state of the bones proves, that they were rapidly enveloped by gypsum, before the animal matter in the pores was decomposed, and also that the gypsum was speedily consolidated. The same observation would apply to the bones of land animals found in the freshwater limestone, under the volcanic mountain of Gergovia in Auvergne; the state of these bones was similar to that of those in the Paris gypsum.

Baron Cuvier was the first naturalist who applied the knowledge of comparative anatomy, to ascertain the forms of vertebrated fossil animals. The publication of his *Recherches sur les Ossemens Fossiles*, may be regarded as an epoch in geology: since that time many other important discoveries respecting fossil quadrupeds have been made. It will not therefore be deemed irrelevant to our subject, to insert the very interesting account he has given of his own feelings, when he first became able to arrange the bones of each genus and species of unknown animals, found in the gypsum quarries near Paris. "When the sight of some bones of the bear and the elephant, twelve years ago inspired me with the idea of applying the general laws of comparative anatomy, to the reconstruction and the discovery of fossil species; when I began to perceive that these species were not perfectly represented by those of our day which resembled them the most;—I did not suspect, that I was every day treading upon a soil, filled with remains more extraordinary than any that I had yet seen; nor that I was destined to bring to light whole genera of animals, unknown to the present world, and buried for incalculable ages at vast depths under the earth. It was to Mr. Verrin that I owe the first indications of these bones furnished by our quarries: some fragments which he brought me one day, having struck me with astonishment, I made inquiries respecting the persons to whom this industrious collector had sent any formerly: what I saw in these collections, served to excite my hopes and increase my curiosity. Causing search to be made at that time for such bones in all the quarries, and offering rewards to arouse the attention of the workmen, I collected a greater number than any person who had preceded me. After some years I was sufficiently rich in materials to have nothing further to desire; but it was otherwise with respect to their arrangement and the construction of the skeletons, which alone could conduct me to a just knowledge of the species. From the first moment I perceived, that there were many different species in our quarries; and soon afterwards, that they belonged to various genera, and that the species of the different genera were often of the same size; so that the size alone, rather confused, than assisted my arrangement. I was in the situation of a man who had given to him *pêle-mêle* the mutilated and incomplete fragments of a hundred skeletons, belonging to twenty sorts of animals, and it was required that each bone should be joined to that which it belonged to. It was a resurrection in miniature; but the immutable laws prescribed to living beings were my directors.* At the voice of comparative anatomy, each bone, each fragment regained its place. I have no expressions to describe the pleasure experienced, in perceiving that as I discovered one character, all the consequences more or less foreseen of this character, were successively developed. The feet were conformable to what the teeth had announced, and the teeth to the feet; the bones of the legs and the thighs, and every thing that ought to reunite these two extreme parts, were conformable to each other. In one word, each of the species sprung up from one of its elements. Those who will have the patience to follow me in these memoirs, may form some idea of the sensations which I experienced, in thus restoring by degrees, these ancient monuments of mighty revolutions. This volume will afford much interest to naturalists, independent of geology, showing them by multiplied examples, the strictness of the laws of co-existence, which elevate zoology to the rank of the rational sciences; and which, leading us to abandon the vain and arbitrary combinations that had been decorated with the name of *systems*, will conduct us at last to the only study worthy of our age—to that of the natural and necessary relations, which connect together the different parts of all organized bodies. But geology will lose nothing, by this accessory application of the facts contained in this volume; and thus the numerous families of unknown beings, buried in the most frequented part of Europe, offer a vast field for meditation."

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* In the following passage Cuvier has more fully explained what he denominates "the immutable laws prescribed to living beings." "Every organized being forms a whole and entire system, of which all the parts mutually correspond and co-operate, to produce the same definite action, by a reciprocal reaction; none of these parts can change, without a change of the others also. Thus if the intestines of an animal are organized in a manner only to digest fresh flesh, it is necessary that his jaws should be constructed to devour the prey, his claws to seize and tear it, his teeth to divide the flesh, and the whole system of his organs of motion to follow and overtake it, and of his organs of sense, to perceive it at a distance. It is necessary also that he should have seated in his brain, the instinct to hide himself and spread snares for his victim; such are the general conditions of a carnivorous regimen; every carnivorous animal must infallibly unite them,—without them the species could not subsist. But under these general conditions, there are particular ones with respect to the size of the species and the abode of the prey, for which each animal is disposed."

Upper Marine Sandstone and *Sand.*—At Paris this formation covers the gypsum, or where that is wanting, it rests on the *calcaire grossier*. In England it forms a few isolated caps on the summit of the hills in the Vale of Thames, and an extensive track along the coast of Suffolk and Norfolk, where it rests sometimes on plastic clay, and sometimes on chalk; the intervening beds being wanting. The lowest bed is without shells; it consists almost entirely of siliceous particles, which are sometimes agglutinated, and form sandstone. The loose blocks of stone, (called *gray wethers*,) scattered over some of the southern counties, are of this sandstone, as are also some of the large stones at

Stonehenge.* At the forest of Fontainebleau in France, the thickness of this sand and sandstone, exceeds one hundred and seventy feet; the sandstone occurs in loose blocks and irregular masses, and sometimes is distinctly stratified. It is this stone, which is used for paving the streets and roads in and round Paris; and the sand is so pure in many parts of this forest, that it is employed in making the finest glass. The marine sand on the top of Hampstead Heath, is now nearly cleared away to supply the metropolis; it is composed of minute particles of quartz, sometimes coloured with the oxide of iron: the particles when examined with a microscope, appear to be partly rounded; a few microscopic scales of brillant mica are sometimes intermixed with it. The lower bed of marine sandstone at Paris is without shells, but the upper bed contains numerous marine shells, many of which resemble those in our present seas. The vast tertiary track in Italy below the Apennines, that contains the remains of cetaceous animals,† and extends from Asti in Piedmont, to Monteleone in Calabria, and which has been so well described by M. Brocchi, according to M. Brongniart, belongs in a great part to this formation, similar to what covers the gypsum at Paris.

In no part of England does there occur any extensive bed of the upper marine sandstone with shells, (provincially called *crag*;) except in the counties of Norfolk, Suffolk, and Essex, it is of variable thickness, and is principally composed of sand and loose ferruginous sandstone, containing shells and bones, and mixed with gravel. In a valuable paper on the Geology of East Norfolk, by Mr. R. C. Taylor, published in the Philosophical Magazine and Annals of Philosophy, April 1827, and the following numbers, there is an interesting account of the geological position of the crag near the coast, with explanatory sections. "The crag rests in part upon the London clay, and a laminated clay without fossils, and partly upon chalk, occupying the lowest sites; rarely rising to eighty feet above the present level of the sea; and in general not more than half that elevation. The average level of its base may be considered to be about that of the present ocean. In certain cases, where the chalk hills attain a higher level than the crag, that deposit could only be expected to envelop or surround their sides, and not to penetrate into the chalk: such eminences would then present the appearance of tongues or promontories of chalk, protruding into the crag; and this circumstance accounts for the occasionally apparent absence of that formation. But the crag has been subjected to abrasion by diluvial currents. Portions of its western edges have been swept away. Their fragments, mingled with those of chalk and preceding formations, piled in enormous heaps, form the cliffs of Cromer and Trimingham, two hundred and fifty or three hundred feet in thickness, upon the original crag, which rests *in situ* at their base."—No. 4, (New Series,) p. 288. The crag is in many parts covered by a thick mass of diluvium, which prevents its extension far inland from being observed; but the most remarkable circumstance noticed by Mr. Taylor, is the connection which seems to subsist between the upper surface of the crag, and an "apparently continuous bed of vegetable substances, with which the crag is frequently in contact, at an irregular elevation; sometimes above, and sometimes below the low water mark. At some points this bed consists of forest peat, containing fir cones, and fragments of bones, and in others of woody clay; and elsewhere of large stools of trees, standing thickly together, the stems appearing to have been broken off about eighteen inches from their base. They are evidently rooted in the clay or sandy bed in which they originally grew, and their stems and branches lie around them, flattened by the pressure of from thirty to three hundred feet of diluvial deposits. It is not possible to say how far inland this subterranean forest extends; but that it is not a mere external belt is obvious, from the constant exposure and removal of new portions, at the base of the cliffs." This fact, mentioned by Mr. Taylor, is highly deserving of notice; as it is evident, that we have here one of those extensive lignite formations in or over tertiary sand and sandstone, to which continental geologists give the name of *gres à lignites:* it further appears to point out the geological relation of the crag with the upper beds of molasse in Switzerland; and what is still more important, it gives us the true geological position of the subterranean forest, that extends in the eastern side of England into Yorkshire, and to which I shall refer again in a subsequent chapter. The fossils in the crag are not mineralized; many of them appear to belong to species living in the present seas. The general characters of the crag are ably given by Mr. Taylor. "A district, bordering a hundred miles upon our eastern coast, is occupied by an ancient marine deposit, continually changing its aspect, yet constant in its peculiar characters, and always to be understood by unerring data: now appearing as a ferruginous sandstone, then in compact clay, and again considerably indurated; sometimes blended in a mass of extinct zoophytes, sponges and alcyonites, forming a soft rock; oftener an irregularly accumulated mass of decomposed and broken littoral shells, loosely imbedded in sand like an ordinary sea beach, yet accompanied with the remains of unknown animals. Sometimes forming the substratum of a considerable area; or, overwhelmed beneath the debris of older strata, only detected at intervals. At one point exhibiting groups of shell fish allied to those of the neighbouring sea; and at another, composed of numerous genera, which are neither to be recognised living in any part of our globe, nor assimilating to the fossil shells of other formations."—*Phil. Mag.* p. 350.

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* In all probability the ancient Britons took advantage of finding a groupe of large blocks of graywethers and other diluvial stones, and arranged them near the places where they lay upon the plain. At Brimah Craggs near Knaresborough in Yorkshire, they have evidently availed themselves of the masses of a broken stratum of sandstone, to form rocking-stones and various fantastic figures, which were probably the objects of superstitious veneration.

† Cetaceous animals, of the whale family,—such as dolphins, seals, the manati, or sea-cow, &c.—are warm-blooded mammiferous animals, and therefore belong to a higher class than reptiles. Their bones have not hitherto, I believe, been found in chalk or the lower strata.

A small portion of the upper marine formation occurs in the Isle of Wight and the opposite coast of Hampshire.

Upper Freshwater Limestone.—This formation, though extensively spread over many parts of the continent, is scarcely known in England: it occurs in the Isle of Wight. In the Paris basin it covers all the other tertiary strata, and is itself covered with vegetable soil. Below the freshwater limestone there is sometimes a bed of sand, intermixed with greenish or reddish earth, and millstone: the upper part of the freshwater limestone also becomes intermixed with siliceous earth, and passes into millstone.

This millstone has generally a reddish or yellowish colour, but that of the best quality is white; it is penetrated by a multitude of irregular cavities, in which there are numerous siliceous filaments: these cavities are lined with an ochreous coat, but are sometimes filled with argillaceous earth or sand; they do not communicate with each other: the substance of the millstone, when unmixed, is pure silex. All the best millstones in England are brought from France, and are known by the name of Burr stones.

Freshwater limestone in the vicinity of Paris, has generally a grayish white, or a yellowish colour; it is sometimes as tender as chalk, and sometimes hard and compact, with a fine grain and conchoidal fracture: in the latter state it is brittle, and breaks into sharp-edged fragments like flint. Some of this limestone, particularly that of Chateau Landon, presents the character of a transition marble, and will receive a fine polish. Several of the basins with *jets d'eau* in the gardens of the Thuilleries are made of this marble. Many of the harder freshwater limestones, however, rapidly disintegrate on exposure to air and moisture, and fall to the state of marle, and are used as manure. This formation is characterized by containing exclusively freshwater and land shells, similar to what are found in the neighbouring marshes; they belong to a small number of genera or species, being chiefly lymnites, planorbes, turbinated shells, (allied to *cerithia*,) cyclostoma, and helices.

Freshwater limestone occurs in many parts of the South of France; in Auvergne it is covered by a vast mass of volcanic tufa and basalt: it contains bones of mammiferous quadrupeds, together with lymnites and freshwater shells. The freshwater limestone under Gergovia, near Clermont, is distinctly stratified, and presents the characters of a soft grayish chalk. The upper freshwater limestone, may be regarded as the most recent rock formation of the ancient world.

For the first accurate account of the tertiary strata, and of the alternation of marine and freshwater strata in England, we are indebted to Mr. Webster, who published, in the 2d volume of the Transactions of the Geological Society of London, a very interesting description of these strata in the Isle of Wight, and their connection with the subjacent chalk. The chalk covered by the London clay, passes under the channel, called the Solent, and rises in the middle of the island, forming a range of hills which extends from Culver Cliffs on the east, to the Needles on the west. Here we meet with the only remarkable derangement of the beds of chalk, and the superior strata, which has been noticed in England. The strata of this range of hills are thrown into a position absolutely vertical, evincing the action of some mighty disturbing force, which can be so often observed to have acted on the lower strata in various parts of the world, and also on the upper strata in the vicinity of the Alps.

The whole thickness of the beds in the Isle of Wight, which are nearly vertical, according to Mr. Webster's measurement is not less than three thousand feet, including fourteen hundred and eighty-one feet of strata above the chalk, about nine hundred and eighty-seven feet of chalk, and five or six hundred feet of lower strata. Further south, the strata under chalk are seen again in their original horizontal position; and on the northern side, there are hills composed of horizontal strata, evidently of a formation posterior to the time when the chalk strata were overturned. That the latter were once nearly horizontal, may be inferred from their always occurring in that position in the southern counties, and is rendered certain from the following circumstance described by Mr. Webster. In one of the vertical beds consisting of loose sand, are several layers of flints, extending from the bottom to the top of the cliff. "These flints have been rounded by attrition, are from an inch to eight inches in diameter, and appear to have belonged to the chalk. Now it is inconceivable that these flints could have been originally deposited in their present position: they distinctly point out the former horizontal direction of this series. There are no signs of partial disturbance in these beds; the whole appears therefore to have been moved together." The enormous force required to occasion a displacement of the strata, not only through the whole island but into Dorsetshire, where it can be traced beyond Lulworth, must have been sufficient to form or destroy extensive lakes, and perhaps to separate England from the Continent.

Close adjoining the vertical strata on the northern side of the island, occur a series of horizontal strata, which are distinctly visible in a hill called Headon;—these strata consist of an alternating series of freshwater and marine deposits, bearing a striking similarity in their fossil contents, to the strata in the vicinity of Paris. According to Mr. Webster, they consist of

1. A calcareous stratum, containing only freshwater shells.—*Upper freshwater.*
2. Greenish marle with marine shells:—*Upper marine.*
3. Marle with freshwater shells.—*Lower freshwater.*
4. Dark blue clay without shells.—*Lower marine.*

Thus we have over chalk four distinct formations. No. 4. A lower marine formation, which includes the London clay. A lower freshwater formation, No. 3. The strata of this formation consist of sandy, calcareous, and argillaceous marle; some of them appear to be formed almost wholly of the fragments of freshwater shells, without any mixture whatever of marine shells. "From the quantity of these shells, and the regularity and extent of the strata, we are compelled (says Mr. Webster) to admit, that the spot where they now are, was once occupied by fresh water, in which these animals existed in a living state. Over this fresh water occurs an upper stratum, No. 2, which contains a vast number of fossil shells wholly marine. Again, over this marine formation, in the same hill, is a calcareous stratum fifty-five feet in thickness, No. 1, every part of which contains freshwater shells in great abundance, without any admixture of marine exuviæ. Many of the shells are in high preservation; and the animals must formerly have lived in the very spots where they now are, the shells being so fragile, that they could not have been removed from their original situation without breaking. Part of the stone of this formation is very hard and compact, and has long been extensively used for building-stone. This stratum appears to have extended over the whole of the northern part of the Isle of Wight; but it has not yet been discovered in any other situation on this side of the water; it may be considered as the latest formation of rock we are acquainted with in England, and agrees in many of its mineralogical characters, and the fossils it contains, with the freshwater limestone, *calcaire d'eau douce*, in the vicinity of Paris; they are different from any other known rock." But no where has there been discovered in the series of freshwater strata in England, any trace of the remarkable beds of gypsum containing bones of unknown genera, and species of quadrupeds, similar to the gypsum of Montmartre.

OBSERVATIONS.

Though the tertiary strata are the most recent of all the regular rock formations, and contain the remains of animals, similar in the essential parts of their organization to the present races of living animals, yet at the period of their deposition, the condition of our planet must have been very different from the present one. Many of the tertiary strata are original siliceous depositions—the mill-stones for instance, with the thick beds of pure siliceous sandstone passing into chalcedonic flint or chert, (*silex corné*) are as evidently original formations as any of the lower rocks. In the present seas or lakes there are no siliceous formations taking place, nor have we any instances of siliceous depositions, except from boiling springs. These considerations will alone be sufficient to convince us, that the tertiary strata were deposited under different circumstances, from any that we have a knowledge of, either from experience or historic records.

The alternation of marine and freshwater formations has been differently accounted for. According to one hypothesis, the sea, which at present contains a variable portion of salt in different latitudes, may formerly have deposited all its salt, and become fresh at one period, and have subsequently received another saline impregnation; there is nothing absurd or highly improbable in this hypothesis, but it is entirely gratuitous. Some geologists deny that freshwater shells are a sufficient proof that the strata in which they are found were not deposited in salt water. In the salt lakes in Westphalia, lymnites, which may be regarded as the most characteristic of all freshwater moluscæ, are observed to flourish together with freshwater plants; and many testaceous animals, it has recently been discovered, will live equally well in fresh or salt water. The number of terrestrial quadrupeds that have left their bones in the freshwater limestone and gypsum, afford, however, a strong presumption, that the water was fresh that filled the lakes, on the banks of which they lived; and the extensive lakes of fresh-water in America render the existence of such lakes in a former state of our planet, highly probable. Nor will the change from salt to fresh water require any forced hypothesis to explain it, if we separate from the investigation, the difficulties which it has in common with other geological problems.

It is granted by all geologists, that the calcareous beds on the summits of the Jura range, or the Pyrenees, have once been covered by the sea. We may therefore grant that the chalk strata were also once under its surface. Now if we admit, that the water in which the strata around Paris were deposited, was surrounded by mountains and dry land, so as to form an inland sea or lake, communicating by a narrow opening with the ocean, and that large rivers flowed into this inland lake; the water would at first be salt; but if by any cause the opening was closed, the water would gradually become fresh again. If at a subsequent period the passage was re-opened by an earthquake or inundation, the sea would once more flow into the lake, and the water would again become salt. Such alternations might take place repeatedly, without any change in the relative level of the ocean. The difficulty of conceiving these alternations, has arisen from supposing that it was necessary for the sea to sink to its present level, and rise again repeatedly; but this is by no means required, to explain the alternate succession of freshwater, and marine formations.

The causes which have depressed the sea to its present level, or have elevated our present continents above its surface, took place after the deposition of the tertiary strata, as might be proved by numerous incontrovertible facts. Whether in a still more remote epoch, all the present continents may not have been repeatedly submerged in the ocean, and again elevated above its surface, is an inquiry not necessarily connected with the deposition of the tertiary strata, as these changes were anterior to their formation.

CHAPTER XV.

ON EARTHQUAKES AND VOLCANIC PHENOMENA.—ON RECENT AND ANCIENT VOLCANOS.—SUBMARINE VOLCANOS.—AND ON VOLCANIC ROCKS AND PRODUCTS.

Accustomed to view the hills in our own country in a state of profound repose, presenting the same unvaried outline in each succeeding year, we can scarcely conceive the possibility of a whole district being covered with new mountains and another soil, in the space of a single night; yet such changes have been produced, by the united agency of earthquakes and volcanos, within the limits of authentic history. For a particular description of recent volcanic eruptions, and the changes they have produced on the surrounding countries, I must refer the reader to the works of Spallanzani, Dolomieu, Sir William Hamilton, and M. Humboldt, and to the recent account of the Island of Java, by lieutenant governor Raffles.

In the present chapter, I propose, 1st, to describe those phenomena that indicate the connection between earthquakes and volcanos, and between the volcanos in distant countries; 2dly, to take a view of the remains of ancient volcanos, that prove the extensive action of internal heat on the crust of the globe; and, 3dly, to give a concise account of volcanic rocks and products.

Earthquakes and volcanos may be considered as different effects produced by the agency of subterranean fire. They frequently accompany each other other; and in all instances that have been observed, the first eruption of a volcano, is preceded by an earthquake of greater or less extent. Volcanos do not make their appearance in every country where the shock of an earthquake is felt: but earthquakes are more frequent in volcanic districts than in any other. Earthquakes are almost always preceded by an uncommon agitation of the waters of the ocean, and of lakes. Springs send forth torrents of mud, accompanied with a disagreeable smell. The air is generally calm, but the cattle discover much alarm, and seem to be instinctively aware of approaching calamity. A deep rumbling noise, like that of carriages over a rough pavement,—a rushing sound like wind,—or a tremendous explosion like the discharge of artillery, immediately precede the shock, which suddenly heaves the ground upwards, or tosses it from side to side, with violent and successive vibrations. The shock seldom lasts longer than a minute; but it is frequently succeeded by others of greater or less violence, which continue to agitate the surface of the earth for a considerable time. During these shocks, large chasms and openings are made in the ground, through which smoke and flames are seen to issue: these sometimes break out where no chasms can be perceived. More frequently stones, or torrents of water, are ejected from these openings. In violent earthquakes, the chasms are so extensive, that large cities have in a moment sunk down and for ever disappeared, leaving a lake of water in the place. Such was the fate of Euphemia in Calabria, in 1638, as described by Kircher, who was approaching the place, when the agitation of the ocean obliged him to land at Lopizicum: "Here (says he) scenes of ruin every where appeared around me; but my attention was quickly turned from more remote to contiguous danger, by a deep rumbling sound, which every moment grew louder. The place where we stood shook most dreadfully: after some time, the violent paroxysm ceasing, I stood up, and turning my eyes to look for Euphemia, saw only a frightful black cloud. We waited till it had passed away, when nothing but a dismal and putrid lake was to be seen where the city once stood."

The extent to which earthquakes produce sensible effects on the waters of springs and lakes in distant parts of the world, is truly remarkable. During the earthquake of Lisbon in 1755, almost all the springs and lakes in Britain and every part of Europe were violently agitated, many of them throwing up mud and sand, and emitting a fœtid odour. On the morning of the earthquake, the hot springs at Toplitz in Bohemia suddenly ceased to flow for a minute, and then burst forth with prodigious violence, throwing up turbid water, the temperature of which was higher than before: it is said to have continued so ever since. The hot wells at Bristol were coloured red, and rendered unfit for use, for some months afterwards. Even the distant waters of Lake Ontario,* in North America, were violently agitated at the time. These phenomena offer proofs of subterranean communications under a large portion of the globe; they also indicate, that a great quantity of gas or elastic vapour was suddenly generated and endeavouring to escape. From the fœtid odour perceived in some situations, it may be inferred that this gas is hydrogen or sulphuretted hydrogen. In other instances it may be steam, which condensing again would produce a vacuum, and occasion the external air to press downwards; which has been observed in mines, immediately after the shock of an earthquake.

The space over which the vibration of the dry ground is felt is very great, but generally wider in one direction than another; and where a succession of earthquakes has taken place in the same district, it is observed that the noise and shock approach from the same quarter. It has been before mentioned, that earthquakes are most frequent in volcanic districts; but the shocks are not the most violent, in the immediate vicinity of volcanos. On the contrary, they are stronger in the more distant part of a volcanic country. The ground is agitated with greater force, as the surface has a smaller number of apertures communicating with the interior. "At Naples and Messina, and at the foot of Cotopaxi and Tungurahua, earthquakes are only dreaded when vapours and flames do not issue from the craters."—(Humboldt.)

The connection of earthquakes with volcanos was noticed by ancient writers, and the latter were properly regarded as the openings, through which the inclosed vapour and ignited matter that occasion earthquakes, found a passage. Strabo in his *Geography* states, that "the town of Regium, situated on the Italian side of the Straits of Messina, was so called, according to Æschylus, from the circumstance that the island of Sicily was rent off from the continent by earthquakes. Proofs of this arise out of the phenomena attending Ætna and other parts of Sicily and of the Lipari Islands, and even the opposite continent. Now, indeed, when craters are opened, through which fire and ignited matter and water are poured out, it is said that the land near the Straits is seldom shaken by earthquakes: but formerly, when all the passages to the surface were obstructed, the fire and vapour confined in the earth, occasioned frequent earthquakes, and the land being rent, admitted the ocean. At the same time, Prochyta and an adjacent island were also torn off from the continent, while other islands rose from the ocean, as frequently happens at this day." Vol. i. page 396.

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* It has been observed during many earthquakes in the Eastern States, that the subterranean noise and motion appeared to commence from the Lakes, and proceed towards the Atlantic Ocean, in a direction from the north-west.

It is highly probable that every extensive earthquake is followed by a volcanic eruption more or less remote, unless (as not unfrequently happens) the elastic vapour immediately escapes from fissures made at the time, in the countries that are the most violently convulsed. An earthquake was strongly felt in Geneva when I was there, February 19, 1822, and did considerable damage in several towns and villages in Savoy and France. A few weeks afterwads, I travelled from Geneva to Lyons, and from thence to the ancient volcanos near Clermont. In the course of my route, I made frequent inquiries respecting the effects of the earthquake: it appeared to have been most strongly felt along the valley of the Rhone, and the shock was not less severe in the volcanic district of Auvergne; its direction was from the south-east; and on that and the following days, there were several eruptions from Vesuvius. The frequency of earthquakes at particular periods is well deserving of notice. In the fourth and fifth centuries some of the most civilized parts of the world were almost desolated by these awful visitations. Thrace, Asia Minor, and Syria, according to cotemporary historians, suffered most severely: the earth was agitated continually for long periods, and flames were seen to burst from the earth, over a vast extent of surface. On the 26th of January, A. D. 447, subterranean thunders were heard from the Black to the Red Sea, and the earth was convulsed without intermission for the space of six months; in many places the air seemed to be on fire, towns and large tracts of ground were swallowed up in Phrygia. On the 20th of May, A. D. 520, the city of Antioch was overturned by a dreadful earthquake, and two hundred and fifty thousand of its inhabitants are said to have been crushed in the ruins. A raging fire covered the ground on which the city was built, and the district around; spreading over an extent of forty-two miles in diameter, and a surface of fourteen hundred square miles.

About the middle of the last century, after the earthquake at Lisbon,—Europe, Africa, and America, were for some time repeatedly agitated by subterranean explosions; as may be seen, by referring to the journals of that time. Ætna, which had been in a state of profound repose for eighty years, broke out with great activity; and according to Humboldt, some of the most tremendous earthquakes and volcanic eruptions ever recorded in history were witnessed in Mexico. In the night of the 19th of September 1759, a vast volcano broke out in a lofty cultivated plain, a tract of ground more than twelve miles in extent rose up like a bladder to the height of five hundred and twenty-four feet, and six new mountains were formed, higher than the Malvern Hills in Worcestershire. More recently (in 1812) the tremendous earthquakes in the Caraccas were followed by an eruption in the Island of St. Vincent's, from a volcano that had not been burning since the year 1718, and violent oscillations of the ground were felt both in the islands and on the coasts of America. It may be inferred from these circumstances, that the cause of earthquakes and volcanic eruptions is seated deep below the surface of the earth; in confirmation of which, it will only be necessary to state, that on the same day on which Lisbon was nearly destroyed, all Europe, and a great part of northern Africa, felt the shock more or less severely; its effects were also sensible across the Atlantic both in the United States, and the West Indies. Incredible as it may seem, one-fourth of the Northern hemisphere was agitated by the same earthquake. The bed of the Atlantic was raised above the surface of the ocean, and flame and vapour were discharged; this was observed by vessels at sea. If we take a terrestrial globe, and cover those parts of it that were thus affected by the earthquake, with black crape, we shall obtain a more distinct idea of the extent of surface shaken, than a mere verbal description can convey. This appears to have been one of the most severe shocks that the old continent had experienced for several centuries. The cause which could effect a simultaneous concussion over such a vast extent, must probably have been seated nearly midway, between the centre of the globe and its surface.

It has been remarked that in general, earthquakes are more severely felt in mountainous than in low countries: this might be expected from the structure of the earth.* In alpine districts, the primary mountains are not pressed with the incumbent mass of secondary rocks, and in such situations the resistance to a force acting from beneath will be much less, as all the weight of secondary rocks is removed. In very violent earthquakes, the secondary strata are broken or agitated; but proofs are not wanting, of lesser vibrations being stopped by their pressure. Humboldt says, he has seen workmen hasten from the mines of Marienburgh in Saxony, alarmed by agitations of the earth that were not felt at the surface. During the earthquake at Lisbon, the miners in Derbyshire felt the rocks move, and heard noises which were scarcely perceived by those above. That an expansive force acting from beneath is the proximate cause of earthquakes, can scarcely be denied; and the prodigious power of steam, when suddenly generated, seems equal to their production, if the quantity be sufficiently great. It is said that a single drop of water falling into a furnace of melted copper, will blow up the whole building. This may be an exaggerated statement; but the prodigious force of steam at high temperatures is well known, and there can be no difficulty in admitting, that if a current of subterranean water were to find access to a mass of lava many miles in extent, and most intensely heated, it would produce an earthquake more or less violent, in proportion to the quantity of steam generated, and its distance from the surface. When the hydrogen gas exploded in a mine near Workington in Cumberland, a shock like that of an earthquake was felt by ships in the river, at two miles distance.

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* See a paper on Earthquakes by the Rev. Mr. Mitchell, Philosophical Transactions, 1759.

The horrid crash like the rattling of carriages, which precedes earthquakes, may be occasioned by the rending of the rocks, or parting of the strata through which the confined vapour is forcing a passage.

In volcanic phenomena, we observe a cause in present activity, that can overthrow mountains, form new islands, and raise up the bed of the ocean: hence the geologist may infer, that the same cause, acting with greater intensity and more extensively, has been the agent employed by the Author of Nature, to elevate new and submerge ancient continents, and to change and renovate the surface of the globe. We are indeed acquainted with no other natural agent, that can have effected the mighty changes which the crust of our planet has undergone. The products of volcanos, particularly of ancient ones, are analogous in their composition and internal structure to the oldest rocks of granite, sienite, and porphyry, and indicate not obscurely, the mode in which these rocks were formed: hence the study of volcanos and volcanic rocks is an important branch of the science of geology. Werner and his disciples, however, held that volcanos were produced merely by the ignition of beds of coal, in the secondary strata.

Volcanos are openings made in the earth's surface by internal fires; they regularly, or at intervals, throw out smoke, vapour, flame, large stones, sand, and melted stone called lava. Some volcanos throw out torrents of mud and boiling water. Volcanos most frequently exist in the vicinity of the sea or large lakes, and also break out from unfathomable depths below the surface, and form new islands and reefs of rock. When a volcano breaks out in a new situation, it is preceded by violent earthquakes, the heated surface of the ground frequently swells and heaves up, until a fissure or rent is formed, sometimes of vast extent. Through this opening, masses of rock with flame, smoke and lava, are thrown out, and choke up part of the passage, and confine the eruption to one or more apertures, round which conical hills or mountains are formed. The concavity in the centre is called the crater. The indications of an approaching eruption from a dormant volcano are an increase of smoke from the summit, which sometimes rises to a vast height, branching in the form of a pine-tree. Tremendous explosions, like the firing of artillery, commence after the increase of smoke, and are succeeded by red-coloured flames, and showers of stones. At length the lava flows out from the top of the crater, or breaks through the sides of the mountain, and covers the neighbouring plains with melted matter, which becoming consolidated, forms a stony mass, often not less than some hundred square miles in extent, and several yards in thickness. The eruption of lava has been known to continue several months. Intensely black clouds composed of a kind of dark-coloured sand or powder, improperly called ashes, are thrown out of the crater after the lava ceases to flow, and sometimes involve the surrounding country in total darkness at noon-day. Towards the conclusion, the colour of the volcanic sand changes to white: it consists of pumice in a finely comminuted state. During an eruption of Ætna, a space of one hundred and fifty miles in circuit was covered with a stratum of volcanic sand or ashes twelve feet thick. When the lava flows freely, the earthquakes and explosions become less violent; which proves that they were occasioned by the confinement of the erupted matter both gaseous and solid. The smoke and vapour of volcanos are highly electrical.

The quantity of lava thrown out during a single eruption of a volcano, seems almost incredible to those who have not observed volcanic countries. Kircher in his *Mundus Subterraneus*, lib. 4, cap. 8, published in 1660, says, that the ejections of Mount Ætna would, if collected, form a mass twenty times as large as the mountain itself; and a few years afterwards, viz. in 1669, the same mountain covered with a fresh current of lava eighty-four square miles; and again in 1775, according to Dolomieu, the same volcano poured out another stream of lava, twelve miles in length, one mile and a half in breadth, and two hundred feet in height. Hence it is evident, that the seat of the fire is not in the mountain itself, but deep in the earth: the volcano is not the furnace, but the chimney; and it will be necessary to bear this in mind, if we would form an adequate idea of the extensive effects of volcanic action. Seneca appears to have formed a distinct notion of the seat of volcanic fire, when he remarks, that the volcano does not supply the fire, it only affords it a passage, "*in ipso monte non alimentum habet, sed viam.*" The largest known current of modern lava was formed by a volcano in Iceland in 1783; it is sixty miles in length, and twelve broad, equalling in extent any continuous rock-formation in England. The most extraordinary volcanic eruption recorded in history, for the extent of its effects, took place in Sumbawa, one of the Molucca Islands, in April, 1815. It is described in the History of Java by Lieut. Governor Raffles.

"This eruption extended perceptible evidences of its existence over the whole of the Molucca Islands, over Java, a considerable portion of Celebes, Sumatra, and Borneo, to a circumference of a thousand statute miles from its centre, by tremulous motions and the report of explosions; while within the range of its more immediate activity, embracing a space of three hundred miles around, it produced the most astonishing effects, and excited the most alarming apprehensions. In Java, at the distance of three hundred miles, it seemed to be awfully present. The sky was overcast at noon-day with clouds of ashes; the sun was enveloped in an atmosphere, whose 'palpable' density he was unable to penetrate; showers of ashes covered the houses, the streets, and the fields, to the depth of several inches; and amid this darkness, explosions were heard at intervals like the report of artillery or the noise of distant thunder. So fully did the resemblance of the noises to the report of cannon impress the minds of some officers, that from an apprehension of pirates on the coast, vessels were despatched to afford relief. Superstition on the other hand was busily at work on the minds of the natives, and attributed the reports, to an artillery of a different description, to that of pirates. All conceived that the effects experienced might be caused by eruptions of some of the numerous volcanos on the island; but no one could have conjectured that the showers of ashes which darkened the air and covered the ground of the eastern districts of Java, could have proceeded from a mountain in Sumbawa, at the distance of several hundred miles."

The lieutenant-governor of Java directed a circular to the different residents, requiring them to transmit to the governor a statement of the facts and circumstances connected with this eruption. The most remarkable circumstance attending this eruption, is the distance at which the explosions were heard in the islands of the Indian Sea. "From Sumbawa, to the part of Sumatra where the sound was noticed, is about nine hundred and seventy geographical miles. From Sumbawa to Ternate is a distance of about seven hundred and twenty miles. The distance to which the cloud of ashes was carried so thickly as to produce utter darkness, was clearly pointed out to be the Island of Celebes, and the district of Grisik in Java: the former two hundred and seventeen nautical miles in a direct line, the latter more than three hundred geographical miles." The greatest distance at which the eruption of any volcano had been previously heard, is six hundred miles: according to M. Humboldt, the explosions from Cotopaxi are sometimes sensibly heard at that distance from the volcano, which is one of the largest and highest in the American continent.

The long period of repose which sometimes takes place between two eruptions of the same volcano, is particularly remarkable. From the building of Rome to the 79th year of the Christian æra, no mention is made of Vesuvius, though it had evidently been in a prior state of activity, as Herculaneum and Pompeii, which were destroyed by the eruption of that year, are paved with lava. From the 12th to the 16th century it remained quiet for nearly four hundred years, and the crater was overgrown with lofty trees. The crater was descended by Bracchini, an Italian writer, prior to the great eruption of 1631: the bottom was at that time a vast plain, surrounded by caverns and grottoes. Ætna has continued burning since the time of the poet Pindar, with occasional intervals of repose, seldom exceeding thirty or forty years.

The eruptions of the Peak of Teneriffe have been very rare during the last two centuries. According to Humboldt, "the long intervals of repose appear to characterize volcanos highly elevated.* Stromboli, which is one of the lowest, is always burning; the eruptions of Vesuvius are rarer, but still more frequent than those of Ætna. The colossal summits of the Andes, Cotopaxi and Tungurahua, scarcely have an eruption once in a century. The Peak of Teneriffe seemed to be extinguished for ninety-two years, when it made its last eruption by a lateral opening in 1798. In this interval Vesuvius had sixteen eruptions." The greatest eruptions of lava from Ætna and Vesuvius are always from the sides of these mountains; but these lateral eruptions, finish by an ejection of ashes and flames from the crater at the summit of the mountain. In the Peak of Teneriffe, an eruption of lava from the summit has not taken place for ages; and in the recent great eruption of 1798, the crater remained inactive, nor did its bottom fall in.

Those who are acquainted with the laws of hydrostatics, and know the immense power that would be required to raise even a column of water from the level of the sea, to the top of Ætna or Teneriffe, will not be surprised that the lava forces itself out of the sides, and rarely rises to the top of the crater, in lofty volcanic mountains. It has been calculated, that the force required to raise a column of lava to the height of the summit of Teneriffe, (twelve thousand five hundred feet,) would be equal to that of one thousand atmospheres; and M. Daubuisson, who has made the calculation, states, that if an opening were effected in the volcano at the level of the sea, under the above pressure, the lava and stones would be forced out with a velocity equal to two hundred and seventy metres or eight hundred feet per second.— Tom. i. p. 173.

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* This observation of M. Humboldt will not be found universally correct; for the small volcano of Vulcano, one of the Lipari islands, was in a dormant state thirteen hundred years.

The elevation of volcanic craters varying, as Humboldt observes, from six hundred to eighteen thousand feet, must not only influence the frequency of their eruptions, but must modify also the quality of the substances ejected.—"Some volcanos only eject lava from their sides, like Teneriffe, although it has a crater on its summit; others have lateral eruptions as I observed at Antisana in Quito, at the height of thirteen thousand feet, and their summit has never been pierced. Others equally hollow in their interior, as many phenomena indicate, act only mechanically on the surrounding country, breaking the strata and changing the surface of the soil; thus the volcanic mountain of Chimborazo, with its dome of volcanic porphyry, (*trachyte*,) at the height of twenty-two thousand two hundred feet, has no permanent aperture on its summit or its sides; the small crater by which its eruptions are effected, is placed on the plain of Calpi. The volcano of Pichinca, fifteen thousand feet high, and which I have particularly studied, has never ejected a current of lava since the excavation of the present valleys. On the contrary, the volcano of Popocateptl in Mexico, sixteen hundred feet in height, pours out narrow currents of lava, like those from the smaller volcanos of Auvergne or Italy."

Submarine volcanos are preceded by a violent boiling and agitation of the water, and by the discharge of volumes of gas and vapour, which take fire and roll in sheets of flame over the surface of the waves. Masses of rock are darted through the water with great violence, and accumulate till they form new islands. Sometimes the crater of the volcano rises out of the sea during an eruption. In 1783, a submarine volcano broke out near Iceland, which formed a new island; it raged with great fury for several months. The island afterwards sunk, leaving only a reef of rocks. In December, 1720, a violent earthquake was felt at Tercera, one of the Azores; the next morning a new island nine miles in circumference was seen, from the centre of which rose a column of smoke; it afterwards sunk to a level with the sea. A small island was formed in 1811 by a submarine volcano at a little distance from St. Michael's, one of the Azores: it was a mass of black rock, described by the captain of the Sabrina frigate, who witnessed its formation, to be equal in height to the high Tor at Matlock. A gentleman who visited the Azores in 1813, informs me that it has sunk down and disappeared: there is now eighty fathoms of water in the place.

Near Santorini, in the Grecian Archipelago, submarine volcanos have repeatedly burst forth during the last two thousand years, and formed several new islands: three of the ancient eruptions are recorded by Pliny, Strabo, and Seneca. The last eruption was in the year 1767.

If the sea or large lakes, have once covered our continents, it follows that the greater part of the present and ancient volcanos were once submarine. I am informed by Mr. Leckie, that calcareous strata with organic remains rest on beds of volcanic tufa on the eastern side of Sicily, and decline towards the sea. The alternations of strata of tertiary limestone with beds of lava on the side of Ætna near Lentini, are described by Dr. Daubeny. (See p. 210.) These facts indicate that the volcanic fires in the vicinity of Ætna once raged under the ocean. Almost all the new volcanos on record, have broken out from under the sea.

Some volcanos in Europe, and many in the Andes, throw out aqueous torrents intermixed with mud and stones; indeed, the American volcanos more frequently eject mud than lava. Eruptions of water from Ætna and Vesuvius are rare, and some which have been described as flowing from the crater of the former, have been merely the torrents of melted water from snow on its summit. The volcano of Macaluba in Sicily presents the phenomena of mud, water, and stones thrown out of the crater. Ferrara describes an alarming eruption which took place on the 29th of September 1777: "Dreadful noises were heard all round; and from the midst of the plain, in which was formed a vast gulf, an immense column of mud arose to the height of about one hundred feet, which abandoned by the impulsive force, assumed the appearance of a large tree at the top. In the middle, stones of all kinds and sizes were darted violently and vertically, within the body of the column. This terrible explosion lasted half an hour, when it became quiet; but after a few minutes resumed its course, and with these intermissions continued all the day. During the time of this phenomenon, a pungent odour of sulphuretted hydrogen gas was perceived at a great distance, to the surprise of the inhabitants, who did not dare to approach this spot on account of the horrible noises. But many came the following day, and found that the new great orifice had ejected several streams of liquid chalk (*creta;*) which had covered, with an ashy crust of many feet, all the surrounding space, filling the cavities and chinks. The hard substances ejected were fragments of calcareous tufa, of crystallized gypsum, pebbles of quartz, and iron pyrites, which had lost their lustre, and were broken in pieces. All these substances form the outward circuit at this day. The unpleasant smell of sulphur still continued, and the water which remained in the holes was hot for many months, while a keen smell of burning, issued from the numerous orifices around the great gulf, which is now completely filled."

Volcanos frequently occur in groups, sometimes arranged along a line as if they had originally been formed over one vast chasm, like the minor volcanos on the sides of Ætna; sometimes they are dispersed irregularly over the surface, and sometimes they are isolated like Ætna, and the Peak of Teneriffe.

The volcanos in South America, Humboldt observes, instead of being isolated or dispersed in irregular groups as in Europe, are arranged in rows, like the extinct volcanos of Auvergne, or the volcanos of Java; sometimes in one line, and sometimes in two parallel lines. These lines are generally in the same direction, as the chain of the Cordilleras, but sometimes (as in Mexico) they form an angle with it of 70°. The volcanos of Mexico he further observes, are placed in a narrow zone between latitude 18° 59′ and 19° 12′. This he regards as a vast chasm, seven hundred and fifty miles in length, extending from the coast of the Atlantic, to that of the Pacific, and to the islands of Revillagiedo in the same direction.

Our knowledge of volcanic geography is at present imperfect, but among the principal volcanic groups and ranges, the following may be briefly enumerated.

In the Azores, there are no less than forty-two active or dormant volcanos, and submarine volcanos not unfrequently break forth in their vicinity. Almost all the other Islands in the Atlantic, and many of the West Indian Islands, are volcanic. Numerous Islands in the Pacific Ocean, and the Indian Seas, have large volcanos: in the Island of Java alone, there is a range consisting of thirty-eight large volcanic mountains, some of which are at present in an active state; they are detached from each other, and though some of them are covered by the vegetation of many ages, the indications of their former eruptions, are numerous and unequivocal.

Numerous volcanos exist, near or within the Arctic circle, in Kamschatka, in Greenland, and in Iceland. A range of active or dormant volcanos extends from the southern extremity of America, to the northern, along a line of six thousand miles in length. Of the volcanos in northern Asia, or the interior of Africa, we have little information, and the volcanos covered by the sea, cannot be estimated; but from the above statement, we are authorized in believing, that volcanic fires are more extensively operative, than many geologists are disposed to admit.

Numerous facts might be cited, to prove the connection which exists, between volcanos at a vast distance from each other. In 1783, when a submarine volcano near Iceland, suddenly ceased its eruptions, a volcano broke out two hundred miles distant in the interior of the Island. On the night in which Lima and Callao were destroyed by an earthquake, four new volcanos broke out in the Andes. The source of volcanic fire is seated deep under the surface of the earth; were it not so, the ground in their vicinity would sink down. Yet Ætna has continued to pour out streams of lava for three thousand years, and Stromboli has had daily eruptions, for nearly as long a period.*

There are some instances, of volcanos having been entirely engulphed in the chasms beneath them. The volcano of the Pic in the Island of Timor, one of the Moluccas, is known to have served as a prodigious watch-light, which was seen at sea at the distance of three hundred miles. In the year 1638, the mountain during a violent eruption entirely disappeared, and in its place, there is now a lake. Many of the circular lakes in the South of Italy are supposed to have been formed by the sinking down of volcanos; but the best authenticated account we have of the destruction of a volcanic mountain, is given by Governor Raffles in his History of Java.

"The Papandayang, situated at the western part of the district of Cheribor, in the province of Sukapura, was formerly one of the largest volcanos in the Island of Java; but the greatest part of it was swallowed up in the earth, after a short but very severe combustion in the year 1772. The account which has remained of this event asserts, that near midnight, between the 11th and 12th of August, there was observed about the mountain an uncommonly luminous cloud, by which it appeared to be completely enveloped. The inhabitants as well about the fort, as on the declivities of the mountain, alarmed by this appearance, betook themselves to flight; but before they could all save themselves, the mountain began to give way, and the greatest part of it actually *fell in*, and disappeared in the earth. At the same time a tremendous noise was heard, resembling the discharge of the heaviest cannon. Immense quantities of volcanic substances, which were thrown out at the same time, and spread in every direction, propagated the effects of the explosion through the space of many miles.

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* Since the period of authentic history, no great changes have taken place in the country around Ætna; but it appears from Virgil, as well as from a passage in Strabo, before quoted, that an ancient tradition existed of a sudden separation of Sicily from Italy.

"Hæc loca, vi quondam et vastâ convulsa ruinâ
Dissiluisse ferunt: cùm protinus utraque tellus
Una foret, venit medio vi pontus, et undis
Hesperium Siculo latus abscidit; arvaque et urbes
Littore diductas angusto interluit æstu."—*Æn*, l. iii.

Probably this separation took place when Ætna emerged from the ocean; the occurrence of beds of limestone with shells upon its sides, proves that it was originally a submarine volcano.

"It is estimated that an extent of ground of the mountain itself, and its immediate environs, fifteen miles long, and full six broad, was by this commotion swallowed up in the bowels of the earth. Several persons sent to examine the condition of the neighbourhood, made report that they found it impossible to approach the place where the mountain stood, on account of the heat of the substances which covered its circumference, and which were piled on each other; although this was the 24th of September, and thus full six weeks after the catastrophe. It is also mentioned, that forty villages, partly swallowed up by the ground, and partly covered by the substances thrown out, were destroyed on this occasion, and that two thousand nine hundred and fifty-seven of the inhabitants perished. A proportionate number of cattle was also destroyed, and most of the plantations of cotton, indigo, and coffee, in the adjacent districts, were buried under the volcanic matter. The effects of this explosion are still very apparent in the remains of this volcano."

It has been already stated, that the volcanos in the Andes, more frequently throw out water and mud, than lava. The damage which these aqueous and muddy eruptions occasion is often prodigiously great. Sometimes the deluge of water attending a volcanic explosion, does not come from the interior of the earth, but from the snow which covers the mountain being rapidly dissolved; but in other instances, it proceeds from the crater. Interior cavities of vast extent and depth containing water, are opened during an eruption, and the water coming into contact with ignited lava, is forcibly driven out, and, according to Humboldt, carries along with it a great quantity of small fishes, which he has denominated *pimelodes Cyclopum.*[*] These fishes are about four inches in length, and are of the same species that inhabit the neighbouring brooks and lakes: the number thrown out is sometimes so great, that their putrefaction contaminates the air, and occasions serious maladies among the inhabitants of the adjacent country.

Though the water ejected from volcanos may in many instances be regarded as of accidental occurrence, I conceive it to be different from those muddy eruptions, which cover large tracts of country with strata containing bituminous or inflammable matter: these strata are as essentially volcanic products, as the matter thrown out of the volcano of Macaluba in Sicily, which never ejects lava; and we are hence instructed, that one of the substances which promotes volcanic combustion is bitumen or carbon. The muddy eruptions in the Andes, when first ejected, have little consistence or tenacity; but they soon become hard, and form what is called by the inhabitants *moya;* it is dark coloured and soils the fingers, and is used instead of turf for fuel.

Boiling springs, and thermal waters, must be classed with volcanic phenomena; for it can scarcely be doubted, that the geysers in Iceland, which throw up columns of boiling water, at intervals, to the height of seventy or eighty feet, are occasioned by the subterranean fires which extend under that island: to the same cause must be ascribed the boiling fountains in the Island of St. Michael, one of the Azores. The hot springs in the vicinity of the Pyrenees, in Italy, and in other parts of the world, may with much probability be supposed to have a similar source of heat. The unvaried equality of their temperature for centuries, proves that this source lies far below the agency of those causes which operate on the surface. It has been remarked, that hot springs are most frequent in volcanic and basaltic countries. Though no active volcano exists in the Pyrenees, M. Dralet, in his *Déscription des Pyrenées*, says, "that the hot springs and frequent earthquakes in different parts of this chain, offer proofs of the present operation of subterranean fires." Some notice of the thermal springs in the Alps has been taken Chap. V. p. 79.

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[*] It ought to be stated, that the existence of internal cavities filled with water supplied from the melted snow, is an inference from volcanic phenomena, which, however reasonable it may appear, it is impossible to prove.

However powerful the effects of subterranean fire may be in various parts of the globe, we must conclude from the remains of ancient volcanos, that in a former period, the action of volcanic fire has been far more extensive and intense than at present.

According to Breislak, an Italian geologist, in a space of twenty miles in length and ten in breadth, between Naples and Cumea, there are no less than sixty craters, some of them are larger than that of Vesuvius; one of them is two miles in diameter.

The city of Cumea, founded twelve hundred years before the Christian æra, is built in the crater of an ancient volcano. In other parts of Italy, there are undoubted vestiges of ancient volcanos. In Sicily, there are a number of extinct volcanos, beside those connected with Ætna. Many islands in the Grecian Archipelago are volcanic. There are remains of large volcanic craters in Spain and Portugal: and the extinct volcanic mountains in the middle and southern parts of France, cover several thousand square miles. On the eastern banks of the Rhine, in the Brisgau, and the environs of Andernach, there are numerous extinct volcanos.

It is further to be noticed, that the craters of ancient volcanos are many of them of far greater size than the present ones. Vesuvius is a comparatively small cone, raised within the crater of a larger volcano. The cone of the Peak of Teneriffe, according to the description of travellers, stands within a volcanic plain, containing twelve square leagues of surface, surrounded by perpendicular precipices and mountains, which were the border of the ancient crater. If the opinion of M. Humboldt be correct, all these craters are diminutive apertures, compared with the immense chasms through which, in remote ages, subterranean fire has forced a passage through the crust of the globe.

"The whole of the mountainous parts of Quito," he says, "may be considered as one immense volcano, occupying more than seven hundred square leagues of surface, and throwing out flames by different cones, known by the denominations of Cotopaxi, Tungurahua, and Pichincha. In like manner," he adds, "the whole groupe of the Canary Islands is placed as it were on one submarine volcano. The fire forces a passage sometimes through one, and sometimes through another of these islands. Teneriffe alone contains in its centre an immense pyramid terminated by a crater, and throwing out from one century to another, lava by its flanks. In the other Canary Islands, the different eruptions take place in various parts, and we nowhere find those isolated mountains to which volcanic effects are restrained. The basaltic crust formed by ancient volcanos seems every where undermined; and the currents of lava seen at Lanzerote and Palma remind us," he adds, "by every geological affinity, of the eruption which took place in 1301 at the Isle of Ischia, amid the tufas of Epimeo."

In the preceding part of the present chapter, I have endeavoured to give a succinct account of the most important volcanic phenomena. The only formations of hard crystalline rocks in the present day are volcanic; and if we trace the connection that exists between modern and ancient volcanic rocks, and between the latter and the rocks of trap and porphyry, among the ancient rock-formations, we shall extend the dominion of Pluto over a large portion of the globe.

Many of the ancient volcanic rocks have not flowed in currents from limited apertures, like modern lavas. "The volcanic porphyries on the back of the Cordilleras," says M. Humboldt, "are undoubtedly of igneous origin; but the mode of their formation is not like that of modern lavas, which have been erupted since the excavation of valleys. The action of volcanic fire by an isolated cone or crater of a modern volcano, differs necessarily from the action of this fire, through the fractured crust of the globe." It has been observed by the same geologist, that the further back we can trace volcanic eruptions, the greater is the similarity between their products, and the rocks which are regarded as the most ancient;—hence the countries that have been the seats of ancient volcanos, are particularly interesting to the geologist. In Auvergne and the more southern parts of France, there are extinct volcanos of different ages, covering with their products several thousand square miles. The most recent of these volcanos has been extinct or dormant since the records of authentic history, and probably for a longer period. Julius Cæsar, who was encamped on this volcanic soil, and has described the country, makes no allusion to its having been the seat of active volcanos.*

West of the town of Clermont, there is an extensive granitic plain rising about sixteen hundred feet above the level of the river Allier. On this plain, there are numerous cones, and dome-shaped hills, varying in height from twelve hundred to two thousand feet; some of these cones have well-preserved craters, and the cones themselves are chiefly formed of scoriaceous lava. These are the most recent volcanos of that country; their products differ in no respect from those of modern volcanos, except that the lava may often be observed passing to the state of compact basalt, exactly similar to many of the basaltic rocks in Great Britain. That these volcanos are the most recent, is proved by the lava flowing down from them into the present valleys; and hence we are certain, that the eruptions must have taken place, subsequently to the excavation of the valleys. There are other currents of lava from more ancient volcanos, that have flowed before the valleys were excavated, and form isolated caps on the hills that inclose the present valleys. These currents of lava are composed chiefly of compact basalt: the position of these isolated caps of basalt, is similar to that on the hill *b*, (Plate 3. fig. 2.) but they are not always columnar. The openings from whence these beds of basalt have flowed, cannot be always traced: but as we can observe the change from scoriaceous lava to basalt in the currents of undoubted lava, we cannot hesitate to admit, that the basalt which forms these caps, must have had a similar origin. Under the caps of basalt, there are in many situations thick beds of volcanic tufa, containing bitumen, which will be subsequently noticed. Beside the volcanos with craters, that have ejected currents of scoriaceous lava and basalt, and poured them into the valleys: and beside the more ancient volcanos, that have formed beds of basalt before the excavation of the valleys,—there are other volcanic mountains, which have rounded summits or domes, without any perforation or crater, and these are composed chiefly of whitish or gray earthy felspar, containing imbedded crystals of felspar: to this rock the name of trachyte has been given on account of its rough fracture. It may be properly called a volcanic porphyry.

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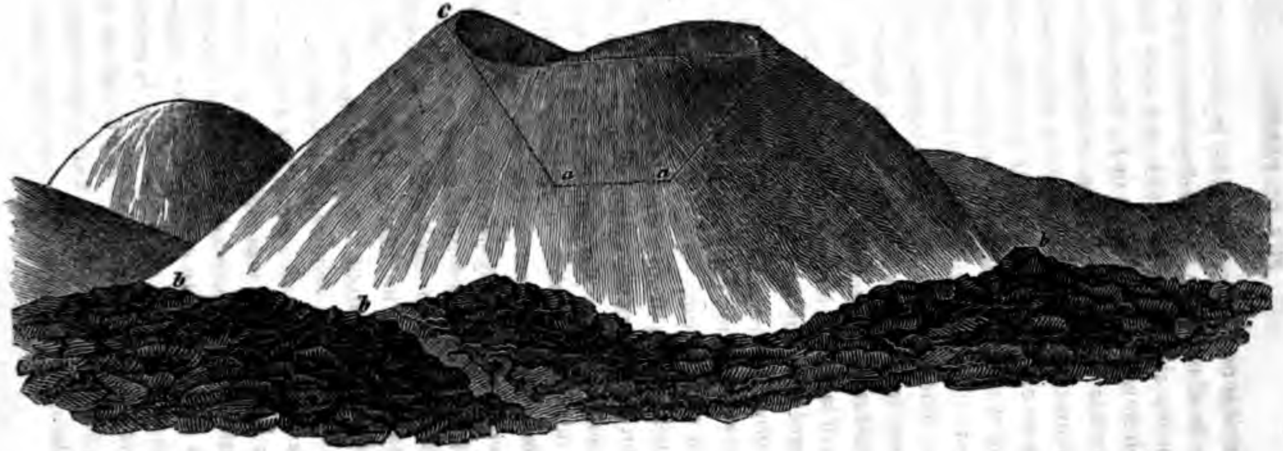
* I visited the extinct volcanos of France in the spring of 1822, and published an account of them in the 2nd volume of my Travels, accompanied with cuts, and a section and outline of the country round Clermont, which is I believe the first attempt to render in this manner the structure of this volcanic district intelligible to the general reader. Without the aid of sections and diagrams, it is difficult to obtain a distinct notion of the relative position of the different volcanic formations.

The first or more recent volcanos, resemble in every particular the existing volcanos in various parts of the world ; and the currents of lava may be traced from their sides along the granitic plane on which the volcanos stand, and thence into the adjacent valleys for many miles. The lava appears as fresh as the recent lavas from Vesuvius, though it has been exposed to the action of the atmosphere for some thousand years. The Puy de Pariou is the most perfect of these volcanic cones. The following description of it is taken from the 2nd volume of my Travels. "We were one hour in going from La Barraque, a mountain village, to the foot of the Puy de Pariou, where we left our char, and another hour in ascending to the summit, as we halted several times to rest. As nearly as I could estimate, the summit of this mountain rises about one thousand feet above the plain, and is therefore about three thousand eight hundred feet above the level of the sea. The crater, which is the best preserved of any in Auvergne, is nearly circular. I walked round it, and its circumference is about eight hundred yards. Its shape is that of an inverted cone or funnel quite perfect. The edge or rim of the crater is narrow, from which the descent or slope is very rapid on each side; the depth of the crater from the highest part of the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edge (which is on the southern side) to the small plain at the bottom, may be about three hundred and twenty feet; and from the western side, about two hundred and sixty English feet. The lava which flowed from Pariou to La Barraque, and thence towards the plain of Clermont, is generally supposed to have issued from the crater; but had this been the case, the crater would not have been so entire as it is; and I am fully convinced that the eruption of such a mass of lava, must have broken down one of the sides, as at Nugere, which we afterwards visited, and the Puy de Vache. There appear, I think, decisive marks of the lava having flowed from an opening on the north-east side of the mountain, to which it may be traced. Indeed on this side there are the indications of a much larger crater, which has its escarpments turned toward the Puy de Pariou like those of Mount Somma, which are turned towards Vesuvius. The Puy de Pariou, was in all probability a volcanic cone formed within the larger crater by its last eruption of scoriæ.

"The annexed cut, from a drawing I made near the foot of the mountain, represents the external shape of the Puy de Pariou, and the dotted lines show the form and the relative depth of the crater, the bottom of which, *a a*, is about three hundred and twenty feet below the highest part of the rim *c*. The current of lava, *b b*, is on the north-east side of the present mountain. The internal shape of Pariou approaches to quadrilateral, or is that of a cone compressed on each side, and somewhat elongated from north to south. The bottom of the crater is nearly flat; there was a little water, from the recent melting of the snow, remaining in some of the hollows: indeed we were told at Clermont that we should find the crater filled with snow. It was early in May; but the snow was gone, and grass was growing in some parts; others were covered with loose masses of scoriæ. Owing to the great porosity of the soil, the crater of Pariou seems doomed to perpetual sterility,—there is no tree or shrub within it; while that of Vesuvius, after a cessation of eruptions for only four centuries, was covered with large chesnut trees."—Vol. ii. page 307.

In the Puy de Pariou, and many other volcanic mountains of this district, there is nothing particularly remarkable, except, that the lavas which have flowed from them at a remote period, should preserve all the freshness of recent lavas, and that volcanos so well characterized, both by their forms and mineral products, should have remained unnoticed until the middle of the last century. The round-topped or dome-shaped hill on the left of the Puy de Pariou is called Sarcoui; it belongs to that class of volcanos that have no craters, which will subsequently be noticed. The more ancient volcanos, that have poured out the thick beds of basalt that cap many of the valleys round Clermont, cannot always be traced, as the openings from whence it issued, may be covered by the lava of more recent eruptions. But in order to obtain a more distinct idea of the position of these caps of basalt, it will be necessary to remark, that the granitic plain above Clermont, and the hollows or valleys in its sides, received their present form prior to the most ancient volcanic eruptions; these hollows, or ancient valleys, were probably basins or lakes, in which were deposited a vast thickness of calcareous strata, containing freshwater shells, and the bones of land quadrupeds. Into these lakes, there has flowed a vast mass of volcanic tufa, covering the limestone, and sometimes intermixed with it. The volcanic tufa, and the freshwater strata, appear to have filled up the ancient valleys or lakes; and on this tufa, the basalt was deposited by a subsequent eruption. At a later period, diluvial currents have furrowed excavations or new valleys in the basalt, the subjacent tufa, and the freshwater limestone, leaving detached portions or hills, composed of basalt, tufa, and limestone, which once were parts of continuous beds. Into these new valleys, the lava of the most recent volcanos has flowed. The most remarkable circumstance attending these more ancient eruptions, is the bituminous nature of the tufa, which forms the lowest bed, and covers the freshwater limestone of Gergovia, Canturges, and the neighbouring hills. This tufa is in some parts more than three hundred feet thick; it consists of earthy basalt or wacke, intermixed with lumps of scoriæ and basalt, and in some places with limestone: it is every where impregnated with bitumen. The tufa of Auvergne bears evident marks of being the product of an aqueous or muddy eruption, intermixed with lava and scoriæ, which increase in quantity in the upper part of the mass, and at length cover it with compact lava or basalt. That the tufa was ejected in an aqueous or muddy state is proved, by the quantity of bitumen which it contains: by any other mode of formation, the bitumen would have been consumed. By some former writers it has been supposed, that the tufa is an alluvial bed of sediment, and water-worn fragments; but the bituminous nature of this bed, excludes the probability of this mode of formation; and at Montadoux, the upper part of the tufa may be clearly seen passing into basalt. In some situations, however, the tufa has been transported from its original situation, and intermixed with fragments of more ancient rocks.

The dome-shaped hills without craters, composed of volcanic porphyry or trachyte, have given rise to much speculation respecting their origin. Some geologists contend, that they are only the remains of one vast bed of trachyte, of which the other parts are washed away. Others contend, that they are merely portions of the granite on which they rest; and that this granite has been wholly or partially fused, and upheaved, by the expansive force of subterranean fire. This mode of formation is rendered probable, by what may be observed at the Puy de Chopine, which is a mountain standing within a crater; this mountain is composed partly of unaltered granite and sienite, and partly of volcanic trachyte, and appears to have been upheaved, before the fusion of the granite had been effected.

The Puy de Dome near the summit is composed chiefly of whitish trachyte intermixed with unaltered granite; the lower part of the mountain is covered with scoriaceous and compact lava. The dome of this mountain rises two thousand feet above the elevated granitic plain on which it stands, and four thousand seven hundred and ninety-seven feet above the level of the sea: it has no crater or opening on the top; but Dr. Daubeny says, two streams of lava appear to have pierced the sides of the mountain, and to have descended into the valleys. In this respect the

Puy de Dome resembles the enormous dome of trachyte on the summit of Chimborazo, twenty thousand feet above the level of the sea, which, according to Humboldt, acts mechanically on the neighbouring country, fracturing the strata, and changing the surface of the soil; but it has no permanent opening, either on its summit or sides. In some of these dome-shaped hills, the action of subterranean heat appears to have been so intense, as to reduce the whole into a spongy pulverulent mass. But what is remarkable, in the middle of this spongy mass, lumps of scoriaccous lava are sometimes found. It has been objected to the formation of trachyte or volcanic porphyry from granite, that it contains a very small portion of quartz; but in this respect, it resembles many granite rocks in Auvergne, in which the quartz is scarcely perceptible.

In the volcanic districts south of Clermont, the porphyry becomes more compact, and assumes the hardest state of that rock; the base of the stone is sometimes green, and the crystals of felspar white: it will receive a fine polish like the green porphyry of the ancients.

The basaltic rocks also extend south of Clermont, into the districts called the Velay and Viverrais, and cover a great portion of the soil. Near Monpezat, Thueys and Jaujac, according to M. Faujas St. Fond, there are small volcanic mountains, with distinct currents of lava, that appear to issue from their feet, and flow into the valleys. The lower part of the lava is scoriaceous, but the upper part is hard sonorous basalt, arranged in columns as perfect as those of Staffa or the Giant's Causeway. We have here a decisive proof of the igneous formation of columnar basaltic rocks. "The basaltic formation extends into the South of France, to the borders of the Mediterranean Sea, where, near to Adge, is the extinct volcano of Saint Loup, the cellular lava of which, is employed in the construction of buildings on the canal of Languedoc."—*D'Aubuisson.**

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* In the article "Volcano," which I wrote for Dr. Rees's Cyclopædia, I endeavoured to collect all the most important details of volcanic phenomena then known, and have given an account of different experiments made on lava, by Spallanzani and others, which the limits of the present volume will not allow me to notice.

Pseudo Volcanos.—To the accidental combustion of beds of coal, the Germans have given the name of Pseudo volcanos. There are instances of coal mines having been on fire for many years; but they are too limited in extent or activity, to bear any comparison with volcanic fires. Near Bilston in Staffordshire, there are coal mines which have been continually burning for a long period; the effect of the fire on the beds of clay deserves notice, as it converts them into a substance resembling jasper.

There have been instances of portions of the cliffs of England taking fire spontaneously, and burning for a considerable time; this is at present the case in a cliff near Weymouth. In the last century, after a hot summer and heavy rains, the cliff near Charmouth in Dorsetshire, took fire, and continued burning for several months. When portions of the cliffs near Whitby in Yorkshire fall upon the beach, and become moistened, they are sometimes spontaneously ignited. The same effect takes place in the Staffordshire coal mines: when parts of the bed of indurated clay which forms the roof of the coal fall down, and become moistened, it takes fire spontaneously; and hence this combustible clay is provincially called *tow.* All these instances of spontaneous combustion admit of a satisfactory explanation. The cliffs of Charmouth, and Whitby are composed of lias clay, much intermixed with bituminous and carbonaceous matter, and the sulphuret of iron (iron pyrites:) such is also the composition of the inflammable clay which forms the roof of the coal in Staffordshire; and the clunch-clay which forms the cliffs near Weymouth, is generally very similar in composition to the lias clay of Charmouth and Whitby. Iron pyrites abounds in these cliffs; and it is a well known property of this mineral, to decompose rapidly when laid in heaps and moistened with water. During this rapid decomposition, sufficient heat is evolved to ignite the bituminous matter in the clay: and the clay when once ignited, will burn for a long period;—this is proved in the process employed for making alum at Whitby. There can be little doubt that this spontaneous combustion might be imitated artificially by mixing pyrites and bituminous clay or shale, and moistening the heap with water. The experiment of Lemery is well known: he mixed twenty-five pounds of powdered sulphur with an equal weight of iron filings; and having made with water a paste of the mixture, he put it into an iron pot covered with a cloth, and buried it a foot under ground. In about eight hours the earth swelled and cracked, and hot sulphureous vapours were exhaled; a flame was observed to issue through the cracks, and the ground was covered with a yellow and black powder: thus a subterraneous fire was produced by the chemical combination of sulphur, iron, and water. In the cliffs of Charmouth, Whitby and Weymouth, we have precisely the same mineral substances combined, that are used in the experiment of Lemery.

The earth itself is in all probability the great laboratory, in which by the aid of subterranean heat, are combined and prepared the mineral substances that compose the hard crystalline crust of the globe. All the minerals which form primary rocks, occur in a perfect state in modern or ancient lava. The substances ejected through fissures in the earth, or volcanos, belong to the four grand divisions of the mineral kingdom,—the inflammable, saline, metallic, or earthy.

The inflammable substances are sulphur, carbon, and hydrogen. Though sulphur may be one of the supporters of volcanic combustion, its inflammable nature prevents its being found in lava in a solid form; during volcanic eruptions it is evolved in a gaseous state, combined with hydrogen. It is also sublimed from the fissures of extinct or dormant volcanos, and forms thick incrustations on the sides of the craters. Almost all the sulphur of commerce in Europe is procured from the craters of dormant volcanos in the South of Italy, Sicily, and the Lipari Islands. When the combustion of sulphur in volcanos takes place where there is access to atmospheric air, it forms sulphureous acid gas, and sulphuric acid.

Carbon combined with hydrogen, forming bitumen, is found in volcanic rocks. The volcanic tufa in the vicinity of Clermont in France, contains so much bitumen, that in warm days it oozes out, and forms streams of bitumen resembling pitch, which is the more remarkable, as this tufa must have been erupted some thousand years. Bitumen has been observed oozing out of the lava of Ætna. The moya erupted from the volcanos in the Andes in aqueous or muddy eruptions, contains so much bitumen or carbon, as to be inflammable. As bitumen exists in many volcanic rocks, the black smoke which issues during an eruption, may proceed from its combustion, though it has generally been supposed to consist of minute volcanic sand, called ashes. Carbon also combines with hydrogen in a gaseous state, and forms carburetted hydrogen gas.

The hydrogen gas evolved from volcanos, or from chasms in the earth during earthquakes, is generally combined with sulphur or carbon; it is probably formed by the decomposition of water, when it finds access to subterranean fire. Whether phosphorus be a product of volcanos is unknown: its extreme inflammability prevents it from being discovered in a concrete form; but the dense white clouds like bales of cotton, which sometimes cover Vesuvius, resemble the fumes produced by the combustion of phosphorus. Among the products of volcanos, only three are combustible at a moderate temperature;—sulphur, hydrogen, and carbon. It has been conjectured by Sir H. Davy, that the earths and alkalies which form lavas, exist in the centre of the globe in a metallic state, and take fire by the access of water. This property of the newly discovered metals, to inflame instantly on the access of water, by which they are converted into earths or alkalies, offers an easy explanation of the origin of volcanic fires, could we suppose that substances so extremely inflammable and oxidable, have remained for ages in a metallic state. There may, however, be processes going on in the vast laboratory of the globe, that separate the earths from oxygen, and prepare them for the support of volcanic fires, by which they are thrown upon the surface, and thus establish a communication between the internal and external parts of our planet.

The saline products of volcanos are not numerous. The sulphureous and sulphuric acids formed by the combustion of sulphur during eruptions, act upon lavas and rocks, and produce different combinations, of which the most important are alum, sulphate of magnesia, of iron, or green copperas and gypsum. Muriate of ammonia or sal-ammoniac forms an incrustation on many lavas soon after they cool: muriate of soda or common salt, and muriate of copper and of iron, are found in the craters of volcanos. Muriatic acid in an uncombined state occurs in some of the spongy lavas in Auvergne.

The principal metallic substances in volcanic rocks, are iron and titanium; but ores of antimony, copper, and manganese, have sometimes been found in the craters of volcanos. Tellurium, gold and mercury, are also said to occur in some volcanic rocks. The island of Ischia, which is entirely volcanic, contains a mine of gold.

Iron, in the form of brilliant laminæ, called specular iron, occurs in the cavities and fissures of many lavas. Magnetic iron-ore, and oxide of iron, with iron-sand and titanium, form a constituent part of nearly all dark-coloured lavas or basalt.

The earthy products of volcanos are either vitreous, or stony, or scoriaceous, or spongy, or in loose grains or powder. Volcanic rocks are composed chiefly of felspar, and the dark-coloured mineral called augite; they contain also hornblende and grains of magnetic iron ore, with titanium and iron-sand, and the mineral called olivine. Mica, leucite, iron pyrites, garnets, rubies, and zircon, are also found in some volcanic rocks. The different states of lava, whether vitreous, compact, or scoriaceous, depend on the different circumstances under which it has cooled.—See page 159.

Volcanic rocks being composed principally of the two minerals felspar and augite very minutely intermixed, they derive their principal characters from the prevalence of one or other of these minerals. Those lavas in which felspar greatly predominates, have generally a whitish or grayish colour, and melt into a white glass. The lavas which contain a large portion of augite, have a dark colour, and melt into a black glass. According to M. Cordier, all volcanic rocks that have flowed as lava, and which appear the most homogeneous, are composed of microscopic crystalline particles, belonging to a small number of minerals, particularly felspar, augite, olivine, and iron-sand; and the same intermixure of minerals may be observed in all scoriaceous lava and in basalt.—See page 140. To the white or gray lava composed principally of felspar, the French have given the name of *trachyte*, from its breaking with a rough surface.

Trachyte.—Common or stony trachyte, has generally a whitish or grayish colour, a dull earthy fracture, and is more or less fine-grained; sometimes the grains are very minute, and it has then a compact surface, and sometimes a glistening lustre, in which state it becomes pearl-stone. Its hardness is variable; some of the trachytes near Clermont are spongy, and almost friable. Trachyte melts readily into a grayish glass; it generally contains imbedded crystals of vitreous felspar. Acicular or needle-shaped crystals of hornblende, hexagonal crystals of mica, and grains of iron sand, and laminæ of specular iron ore, occur in trachyte. Augite is seldom found in the trachyte of Europe, though it is common in the trachytes of the Andes. The clay-stone of Braid Hill near Edinburgh nearly resembles some of the trachytes in Auvergne, but it is not porphyritic. Trachyte may be regarded as an earthy form of felspar; it is therefore unnecessary to speak of its constituent parts. To the variety of trachyte on the Puy de Dome, M. Von Buch has given the name of *domite*,—a term which the French geologists have properly rejected, as it is only common trachyte, rather whiter than some of the other varieties. It has before been stated that the trachytes in Auvergne were probably formed by the more or less perfect fusion of granite; like the granite of that district, they contain but a very small portion of quartz.

Trachyte occurs in the Lipari Islands in a perfectly vitreous state, forming obsidian or volcanic glass, which is sometimes colourless, and sometimes black; the black variety, however, forms a white glass when melted. The colouring matter being fugitive, is probably bitumen: in this respect, it differs from obsidian formed from dark lava or basalt, the latter melts into a black glass. Pumice appears to have been formed from felspar, or trachyte, exposed to an intense heat which has reduced it to a fibrous mass.

The island of Lipari contains a mountain entirely formed of white pumice; when seen at a distance, it excites the idea, that it is covered with snow from the summit to the foot. Almost all the pumice-stone employed in commerce, is brought from this immense mine. The mountain is not one compact mass, but is composed of balls or globes of pumice aggregated together, but without adhesion. From hence Spallanzani infers that the pumice was thrown out of a volcano in a state of fusion, and took a globose form in the air. Some of these balls of pumice do not exceed the size of a nut, others are a foot or more in diameter. Many of these pumices are so compact, that no pores or filaments are visible to the eye; when viewed with a lens, they appear like an accumulation of small flakes of ice. Though apparently compact, they swim on water. Other pumices contain pores and cavities, and are composed of shining white filaments. By a long continued heat, pumice-stone melts into a vitreous semi-transparent mass, in which a number of small crystals of white felspar are seen. Black or dark-coloured pumice is more uncommon. Humboldt says, he has seen black pumice in which augite and hornblende may be recognised; he is inclined to think that such substances owe their origin to basaltic lavas, which have assumed a capillary or fibrous form by intense heat.

Immense quantities of pumice are sometimes thrown up by submarine volcanos. It has been seen floating upon the sea over a space of three hundred miles, at a great distance from any known volcano; and from hence it may be inferred, that submarine volcanos sometimes break out at such vast depths under the ocean, that none of their products reach the surface, except such as are lighter than water.

Obsidian or volcanic glass so nearly resembles lumps of black glass, that they can scarcely be distiuguished by the unpractised observer. Its broken surface is smooth, conchoidal and shining: the most common colour of obsidian is a velvet black. The thinner pieces are translucent. It is harder than glass, and strikes fire with steel. It is common in the neighbourhood of volcanos, and in some basaltic formations. The obsidian accompanying basalt, contains a large portion of augite, and melts into a black glass as before mentioned; in other respects its mineral characters are the same as those of obsidian from trachyte. In Lipari, one of the volcanic isles, the mountain de la Castagna, according to Spallanzani, is wholly composed of volcanic glass, which appears to have flowed in successive currents, like streams of water, falling with a rapid descent and suddenly frozen. This glass is sometimes compact, and sometimes porous and spongy. Numerous veins of obsidian are said to intersect the cone of Mount Vesuvius, and serve as a cement, to keep together the loose materials of which it is composed.

On the elevated plain which surrounds the conical peak of Teneriffe, there are masses of obsidian, which graduates into pitchstone, containing crystals of white felspar. On the south west side of the peak, there is a stream of vitreous lava or obsidian several miles in length. Colonel Imrie describes a current of lava in the island of Felicuda intermixed with obsidian, which had been flowing with it, and now formed part of the congealed stream. "In some parts the obsidian is seen losing its brilliancy, and passing into granular lava, which becomes similar in colour, fracture, and texture, to the other parts of the stream. Where the obsidian appears in a state of perfect glass, it is very near to where it has been first ejected from the side of the crater, and in a situation where it must have undergone a rapid cooling. In some parts of these congealed streams, I could trace a transition of the obsidian into pumice. In these places, the obsidian contained scattered air globules, which were almost always lengthened in the direction of the stream. These globules gradually augmented in number, until the whole substance became a light, fragile, and frothy pumice."* Obsidian is found in the crater of Vulcano, one of the Æolian islands, and may be seen forming there at the present time.

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* Memoirs of the Wernerian Society, vol. ii, p. 47.

Rocks of trachyte sometimes, though rarely, have a columnar structure; owing to the facility with which trachyte breaks down, it forms beds of conglomerate intermixed with scoriæ and pumice. The more finely comminuted parts of trachyte, intermixed with earthy matter, form beds of tufa. These beds of conglomerate and tufa frequently environ trachytic mountains, and hide from the view of the geologist, their connection with the subjacent rocks.

When trachyte becomes compact and hard, and acquires a laminar or slaty structure, it passes into clinkstone or phonolite, so called on account of its yielding a metallic sound, when struck. —See Chap. V. where it is observed, that dark lava or basalt also passes into clinkstone. Thus it appears that both the light-coloured lava or trachyte, and the dark-coloured lava or basalt, according to the different degrees of heat to which they have been subjected, or the different circumstances under which they have cooled, form volcanic glass, clinkstone, or pumice; and the only difference to be observed in the minerals formed from the trachyte or the basalt, is a difference of colour in the minerals themselves, or in the glass which they yield when melted. Black pumice from basalt is however very rare.* Basaltic dykes, and the overlying rocks of porphyry, trap and basalt, described in the 9th chapter, ought I am persuaded, to be classed with ancient volcanic rocks; but their igneous origin is not yet universally admitted, and it is desirable to separate theoretical views, from a description of facts. This, however, cannot always be done; circumstances which indicate the mode of rock-formations, will deservedly force themselves on our attention; and in stating them fairly, and the inferences which may be drawn from them, we relieve Geology from much of its dryness, and stimulate succeeding observers to a strict investigation of nature.

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* According to the microscopic and mechanical analysis by M. Cordier, of light-coloured and dark lavas, (whether compact or scoriaceous,) it appears that the stony lavas which melt into a white glass, contain ninety per cent of felspar. Those lavas which melt into a bottle green glass or enamel, contain only from fifty-five to seventy per cent of felspar; such are the greenish, grayish, or dark-coloured basalt. On a microscopic examination of dark lava or basalt, it appears to consist of minute crystalline grains. The whitish grains belong chiefly to felspar, but in the lava from Vesuvius, to leucite; a small proportion of these grains are chrysolite. The yellowish or greenish grains belong to augite and hornblende: those of augite are rounded and irregular, with a vitreous fracture, and splendent lustre. The grains

Dark-coloured recent lava does not differ essentially from basalt; it is generally more porous. Probably the compact state of basalt was the result of refrigeration under pressure: it may however be frequently observed in Auvergne, passing into the state of scoriaceous lava. Some of the recent lavas from Vesuvius are compact, and have a glistening lustre, but they are more commonly porous. In some volcanic eruptions, lava appears to have acquired the most perfect fluidity. According to Professor Bottis, who was an eye-witness of the eruption of Vesuvius in 1776, the lava spouted from three small apertures, precisely like water, forming beautiful fountains of fire, which described curves of different dimensions as they fell. In the same year, a current of lava from the summit of Vesuvius flowed with the velocity of a mile and a half in fourteen minutes; it struck upon the lava of 1771, and rebounded into the air, congealing in figures of various shapes. The length of time which currents of lava retain their heat is truly remarkable: the current which flowed from Ætna in 1669 is two miles in breadth, fifteen miles in length, and two hundred feet in depth; it retains a portion of its heat to the present day. Ferrara says, when this lava was perforated at Catania in 1809, flames broke out; and it continued to smoke at the surface after rain, at the beginning of the present century, or 130 years after its eruption.

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of hornblende are long, and assume a prismatic form; they present indications of a laminar structure, and have little lustre. The perfectly black grains are iron-sand, containing iron, combined with titanium; the grains of iron ore (*fer oligiste*) may be known by yielding a red powder when pulverized. Volcanic glass, volcanic scoriæ, and volcanic tufa, are all composed of the same minerals as the most compact lava; and all the most homogeneous dark volcanic rocks, are composed of minute microscopic grains, which are chiefly felspar and augite, with a small proportion of olivine and iron-sand. M. Cordier informed the author, that the microscopic examination of lava was much facilitated, by steeping the piece to be examined in dilute muriatic acid.

Stones of enormous size are frequently projected from the craters of volcanos; but the quantity of matter which they throw out in the state of scoriæ, sand and powder, often exceeds that erupted in the state of lava, and is spread over distant countries: by the percolation of water it becomes agglutinated, and forms beds of volcanic breccia and tufa. Sometimes the tufa is sufficiently solid to be used for building-stone; the Roman pepperino is a volcanic tufa. Pozzolana consists of minute particles of scoriæ, which have been partially decomposed: when mixed with lime it makes a water-setting cement.

Some volcanic rocks decompose rapidly, and form productive soils; other resist the process of decomposition so effectually, that after the lapse of some thousand years, they present all the freshness of the most recent lavas.

Age of Volcanic Rocks.—Nothing precise can be determined with respect to the relative age of volcanic rocks, except in those districts where they occur together, one covering the other. Humboldt, who has attempted to trace the different ages of volcanic formations, observes, that there are trachytes, clinkstones, and basalts, of different ages; but in proportion as we advance towards the more recent volcanic formations, they appear isolated, superadded, and strangers to the soil in which they are found. The lavas from existing volcanos vary at different periods of their eruptions: we may therefore well conceive, that the volcanic masses which during thousands of years have been progressively raised to the surface, under very different circumstances of pressure and refrigeration, should present striking contrasts and analogies of structure and composition.

OBSERVATIONS.

From the various phenomena which volcanos present, we may with probability infer, that the internal part of our planet, is either wholly or partially in an igneous state, however difficult it may be to explain in what manner this heat is generated and confined. In every department of nature, our inquiries are terminated by ultimate facts, beyond which further research becomes vain. The constant generation and emission of light from the surface of the sun is more inexplicable and surprising, than the constant generation of heat in the centre of our planet; but we cannot refuse our assent to the fact, though it is far beyond the power of the human mind to conceive, by what means the particles of light are propelled through space with such astonishing velocity. We are too apt to measure natural operations by their coincidence with the received systems of philosophy, and to make our own ignorance the standard of truth. Had all the volcanos in the world been dormant for the last two thousand years, and were we acquainted with their existence only by the writings of ancient historians, we should discredit the fact, and prove its impossibility by an appeal to established chemical principles; we should further accompany the proof with a pathetic lamentation over the credulity of former times. The descent of stones from the atmosphere was denied during a longer period, though the fact is now established beyond all doubt.

Admitting the existence of central fire in the earth, it is not difficult to conceive that there may be determinate causes, by which its intensity is increased or diminished at certain periods. We know little respecting the operation of electric or Voltaic energy in the laboratory of nature, but from the existence of electric light at the poles, we may infer that electric currents are passing through the earth, and are important agents in many subterranean phenomena. Perhaps the different beds of rock which environ the globe may act like a series of plates in the Voltaic pile, and produce effects commensurate with their vast magnitude. Voltaic energy is capable of supporting the most intense degree of heat without access to atmospheric air, or even in vacuo; and this for an indefinite time.

Whatever origin we ascribe to subterranean fire, there can be no doubt that it will make its way through the surface in those places where the incumbent rocks offer the least resistance, or where they are most fusible. By the access of water to this fire, the sudden evolution of steam, hydrogen gas, and many phenomena of volcanic eruptions, will admit of an easy explanation. Most of the active volcanos being situated near the sea or great lakes, we may infer that water is in some way necessary to the production of volcanic phenomena.

CHAPTER XVI.

ON THE AGENCY OF SUBTERRANEAN FIRE IN THE FORMATION OF ROCKS AND STRATA.

THE numerous volcanos scattered over the globe abundantly prove the existence of fire in the deep recesses of the earth. During a former state of our planet, the internal fire must have been more intense than since the records of authentic history. This is shown by the remains of mighty volcanic craters, which far exceed any that are active at the present time; for, the craters themselves being formed by the eruption of volcanic matter, their size bears evidence to the magnitude of their former operations.

"Those ranges of volcanos, those eruptions through vast chasms, those subterranean thunders, that roll under the transition rocks of porphyry and slate in the new world, remind us by the present activity of subterranean fire, of the power, which in remote ages, has raised up chains of mountains, broken the surface of the globe, and poured torrents of liquid earth in the midst of the most ancient strata. Even in our own days, these torrents of melted earth do not always issue from the craters or sides of volcanic mountains. Sometimes the earth opens in plains, and spreads strata of lava or of mud over a vast extent of country." —*Humboldt, sur le Gisement des Roches.*

We cannot avoid an inquiry respecting the use of these mighty agents in the economy of nature: were we to consider volcanos merely as the vents for internal fires, a further inquiry would arise respecting the utility of these fires; for we ought not to suppose that the laws which govern the interior of our planet, are not directed by the same wisdom which is displayed in the external world.

There are many philosophers who admit in its full extent the doctrine of final causes as evinced in the structure of a plant, or animal; or in other words, who readily grant that all the various parts and organs conduce to one definite purpose; yet they are reluctant to allow that the earth itself is under any other guidance than the brute force of tumultuous elements.

I do not however think it unphilosophical to inquire what office subterranean fires have performed in the economy of nature: Are they accidental appendages, or essential parts of the terrestrial system? The geologists who exclude the agency of fire from the formation of rocks, seem to forget that the only instances we have of hard and crystalline rock formations are volcanic: beds and strata more than thirty miles in length, and of considerable breadth and thickness, have been spread over the surface of the globe in our own times; and according to M. Humboldt, the further back we trace these eruptions, the greater is the similarity between the currents of lava and those rocks which are considered by geologists as the most ancient. The enormous volcanos whose craters are many leagues in extent, had doubtless an important office to perform in nature: and can it be unreasonable to believe, that the earth itself is the great laboratory and storehouse where the materials that form its surface were prepared, and from whence they were thrown out upon the surface in an igneous, aqueous, or gaseous state, either as melted lava, or in aqueous solution, or in mechanical admixture with water in the form of mud, or in the comminuted state of powder or sand? Inflammable and more volatile substances may have been emitted in a gaseous state, and become concrete on the surface.

These primæval eruptions, judging from the size of the ancient fissures and craters, may have been sufficient to cover a large portion of the globe. Nor can it be deemed improbable, that still larger and more ancient craters have been entirely covered by succeeding eruptions. In proportion as the formation of the surface advanced, these eruptions might decline, and be more and more limited in their operation.

It is not necessary to suppose that these subterranean eruptions consisted only of lava in a state of fusion. The largest active volcanos at present existing, throw out the different earths intermixed with water in the form of mud. Nor should we limit the eruptions of earthy matter in solution or suspension, to volcanic craters: the vast fissures or rents which intersect the different rocks may have served for the passage of siliceous solutions to the surface. We know no instances in nature of siliceous earth being held in aqueous solution, except in the waters of hot or boiling springs; and hence it seems reasonable to infer that many siliceous rocks and veins may have been deposited from subterranean waters at a high temperature. In other instances, siliceous earth rendered fusible by an intermixture with alkalies and earths, may have been poured over the bed of the ocean, and by gradual refrigeration, the constituent parts may have separated and formed granite rocks, composed of quartz, felspar, mica, and hornblende. We know nothing analogous to the formation of granite by aqueous solution, but many of the products of ancient volcanos bear a close affinity to granite. Indeed, all the minerals which form the constituents of primary rocks occur in undoubted lava; and many of them, even mica, are found formed in the slags from furnaces; which adds a high degree of probability to the igneous formation of the primary rocks, and rocks of sienite and porphyry.

Calcareous or cretaceous matter is also ejected during aqueous volcanic eruptions: beds of limestone may have been formed by similar calcareous eruptions, in which the lime was sometimes in solution, and sometimes mechanically suspended; and the numerous remains of testaceous animals in limestone, appear to indicate that the calcareous solutions were favorable to the growth of animals, whose coverings contain so much calcareous matter. Nor is it necessary to suppose that these aqueous eruptions were always sudden, and attended with violent convulsions; for, when a passage was once opened, they may have risen slowly and been diffused in a tranquil state, and by gradual condensation may have enveloped the most delicate animals or vegetables, without injuring their external form.

The long intervals of repose between the great igneous eruptions, or aqueous eruptions saturated with mineral matter, may have allowed time for the growth and decay of animals whose remains are found in different strata; whilst the formation of other strata may have taken place, under circumstances incompatible with organic existence: and accordingly we find in the rocks most abounding with organic remains, certain strata in which they never or rarely occur. The same agent which enveloped living animals in mineral matter without injuring their external form, appears in some instances to have immediately arrested the functions of vitality. Petrified fish have been discovered in solid rocks, in the very attitude of seizing and swallowing their prey. A sudden eruption of a hot fluid saturated with the different earths, (or the elements of which these earths are formed,) might destroy in a moment the animals previously existing, and form round them a siliceous or calcareous incrustation, which would protect their remains from further destruction. Werner and the geologists of his school maintain, that all the different rocks that compose the crust of the globe, were originally dissolved in water; and that this water saturated with mineral matter, was capable of supporting animal life: but this is manifestly absurd, unless we suppose that the lives of these animals were preserved by a perpetual miracle,*—whereas if the mineral matter in aqueous solution was poured out and deposited by successive eruptions, at distant intervals of time, the different races of zoophytes and testaceous animals might have lived and flourished in waters like those of our present seas and lakes, and have been destroyed together, by eruptions of mineral solutions, and have been succeeded by a creation of different genera and species.

Ages of comparative tranquillity might elapse in the interval between different eruptions, and beds of gravel and breccia be formed, by the disintegration of the higher parts of the earth. These beds might be afterwards covered by, or intermixed with, the crystalline beds from subsequent eruptions;—and may we not in this manner explain the alternation or intermixture of crystalline rocks, with those of mechanical formation?

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* As an instance of the data which Werner assumes as undoubted facts, take the following:—"In recapitulating the state of our present knowledge, *it is obvious that we know with certainty*, that the flœtz and primitive mountains were produced by a series of precipitations and depositions formed in succession; that these took place from water which covered the globe, existing always more or less generally, and containing the different substances which have been produced from them. We are also *certain*, that the fossils which constitute the beds and strata of mountains were dissolved in the universal water."!!!—*Theory of Veins*, English translation.

As the strata which cover each other are often composed of very different mineral substances, may we not infer, that the successive ancient eruptions, whether igneous or aqueous, contained at different periods, different elementary parts? At the present day, the lavas of succeeding eruptions, even from the same crater, differ both in external character and constituent parts. Hence we may explain the formation of strata of iron-stone and beds of other metallic ores alternating with earthy strata; and we can have little difficulty in the admission, as it is now known, that the bases of the earthy strata are also metallic. Two or more mineral substances may in some instances have been contained in the same fluid, and separated into different masses or strata by the laws of chemical affinity; but it seems impossible to admit, with the Neptunian geologists, that all the substances which compose rocks and strata were coexistent in the same fluid, and that this fluid, after it had deposited only a small part of its contents, was capable of supporting animal life.

The succession of aqueous and igneous eruptions would account for the alternation of igneous rocks, with others of aquatic formation. The occurrence of obsidian and basalt, with clay and sandstone, may be parts of the same series of phenomena; and thus the two opposing systems of Werner and Hutton may both be true to a certain extent, and agree with existing facts. However vast these operations may appear, they sink into insignificance, compared with the bulk of our planet itself. If a three-feet globe were to contain within it a fluid capable of acquiring consistence by exposure to the air, and were this fluid from time to time, to exude through minute cracks or punctures, and form over different parts of the surface, successive coats of varnish, whose aggregate thickness was less than that of a wafer,—this would be a greater change with respect to the artificial globe, than the formation of all the rocks and strata with respect to the earth. And the numerous dislocations and fractures, by subsidence or other causes, are no more in comparison to the magnitude of the earth, than the cracks or inequalities of this superficial varnish would be to a globe of that diameter.

In proportion to the quantity of matter thrown up from the interior of the earth, might be the subsidence of the surface in other parts; and as the waters retired further from our present continents, the size of the lakes which then covered them would be diminished: but their number would be increased, and also the number of local, or independent, formations of strata. Similar causes still continuing to operate in different situations, might produce general features of agreement amidst the diversity of rock formations which were taking place. Now this is precisely what we observe in comparing the succession of rocks in distant countries.

If subterranean fire has acted intensely on any part of the crust of the globe already formed, it may have upheaved the bed of the ocean, and occasioned subsidences in other parts; and these changes may have been often repeated. According to some recent and interesting experiments of Sir James Hall, the vapour from salt water intensely heated under pressure, will by passing through loose sand, agglutinate the particles, and form solid sandstone. In this manner the heated and compressed water of the ocean, may have consolidated the loose sand at the bottom, and formed strata of sandstone: there are, however, sandstones which are so pure and crystalline, that we must regard them as original siliceous depositions.

Granite, porphyry, sienite, greenstone and basalt, pass by insensible gradations into each other, and into rocks known to be volcanic: hence the probability of their having a similar origin is greatly increased. And if the internal fires that have acted successively on the surface of the globe, were of vast extent, as the remaining craters indicate, they may also in numerous instances have melted or softened pre-existing rocks and strata and occasioned the bending and contortions of the strata, and other phenomena, on which the theory of Dr. Hutton was founded. The defect of that theory consists, I conceive, in extending the operation of this cause, further than existing appearances will support.

Were we to admit that rocks were produced by successive igneous and aqueous eruptions, poured through craters and fissures of the surface, these, with subsequent elevations and subsidences of the surface, might be sufficient to explain all the various phenomena which the position, contortion, succession, and alternation of rocks and strata present to our notice. In some situations granite mountains are covered with a series of schistose rocks, to which succeeds transition limestone; and on this are laid the sandstones of the coal formation. In other instances these sandstones rest immediately on granite, without the intervention of schistose rocks. Here then we may suppose, that no eruptions of matter took place between the formation of the granite and the sandstone; while in other situations, a succession of formations had produced all the intermediate rocks. In some countries the eruption of matter which formed granite, after ceasing for ages, had again taken place; and thus sometimes we find granite covering rocks to which it is most frequently subjacent. To a like cause may we ascribe the occasional appearance of beds similar to the lower rocks, alternating with or appearing in the upper strata. The siliceous and calcareous solutions in a state of tranquillity, might also envelop the fragments and sand from pre-existing rocks, and form the various breccias and aggregated sandstones. Saline and bituminous matter may have been thrown up in detached lakes, and subsequently consolidated, as in the pitch-lake in the island of Trinidad. The local formation of beds of trap alternating with other rocks, has been before alluded to, and the gradation of basalt into clay, or sand, will be consistent with this mode of formation. Many of the solutions containing terrene matter might be erupted at a boiling temperature, like the siliceous water thrown out of the hot springs in Iceland; and on cooling they might deposit their contents, the matter from each eruption forming a separate layer or stratum.*

In some parts of the earth, the quantity of matter thrown out during one eruption, may have been sufficiently great to admit the crystallization of whole groups of mountains: in other instances, it may have been so widely diffused as to form very thin strata. And here it may be proper to remark, that different beds and strata are not arranged in nature in the order of their specific gravity; the lowest are not always the heaviest: neither are they arranged according to their more perfect crystallization; for, though generally the lower rocks are more crystalline than the upper, we not unfrequently find some of the upper strata, more perfectly crystalline than the subjacent rocks. Now if the matter of which the upper and lower rocks are formed, had been coexistent in the same fluid medium, one or other of the above effects must have taken place; but if each stratum were formed by a separate eruption and deposition, they might vary both in specific gravity and degrees of crystallization, without any regard to the order in which they were deposited.

In endeavouring to trace the causes of very complicated phenomena, those explanations are to be preferred, which apply to the greatest number of cases, and are consonant with existing or analogous facts. Now I conceive that the alternation of aqueous and igneous eruptions, offers a more satisfactory explanation of the formation of rocks, than any that has yet been proposed. At the same time it assigns an office to the immense craters and fractures which have once perforated or intersected the globe.

It is an acknowledged maxim, that Nature, or to speak more correctly its divine Author, does nothing in vain;—and can we suppose that the interior part of the earth is constructed with less skill, than what is evinced in the organization of the simplest animal or vegetable? Or, when we contemplate our planet pursuing its trackless path through the heavens with unerring precision, can we believe, that its internal motions are not governed by determined laws, destined to answer the most important purposes in the economy of nature?

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* To compare great things with small,—there is an analogous formation taking place every day, in the channels which receive the boiling waters from some of the steam-engines in the county of Durham. This water contains a large quantity of earthy matter, which is deposited every day, except Sunday, in regular layers that may be distinctly counted, with a marked line for the interval of repose on Sunday, between each week's formation: hence the stone got out of these channels, has received from the country people the name of *Sunday stone*.

Though I am inclined to regard the explanation here offered respecting rock formations, as consonant with existing facts, and as reconciling the phenomena of aqueous and igneous products alternating with or graduating into each other,—facts that appear so contradictory to the theories hitherto advanced,—I would, however, willingly adopt any other explanation that may afford a more satisfactory solution. The Roman poet, after conducting his hero through the subterranean abodes, dismisses him through the Ivory Gate:* and should my readers infer from these speculations respecting the subterranean operations of nature, that I treat them in the same manner, it will not occasion disappointment. Embarked with them in a voyage of discovery, I shall gladly hail the signal for the appearance of solid ground, whoever the fortunate discoverer may be.

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* Æn. lib. vi.

CHAPTER XVII.

ON THE REPOSITORIES OF METALLIC ORES.

Metallic Matter disseminated through Rocks.—Masses of Metallic Ore.—Metallic Beds.—Metallic Veins.—Rake Veins.—Flat Veins.—Accumulated Veins.—Cross Courses.—The remarkable structure of the Botallack Mine worked under the Sea.—On the Formation of Metallic Ores.—Remarkable Phenomena in Mines.—Stream Works.—Rocks in which certain Metallic Ores are found.

THE rocks and strata, and the mineral veins or dykes, described in the preceding chapters, are composed of earthy minerals, sometimes combined with a portion of metallic matter, chiefly iron. The mineral substances to be described in the present chapter, as forming beds or veins, or irregular masses, or grains imbedded in other rocks, consist of metallic matter either pure or in combination with sulphur, oxygen, or acids. Metallic beds and veins may be regarded as fixed constituent parts of the crust of the globe. The difference of external character between a pure metal and an earth is so great, that we find some difficulty at first in conceiving how metallic matter can form beds interstratified with earthy rocks; but the discoveries of modern chemistry have shown, that metallic and earthy minerals are closely allied. Nothing can appear more essentially different than a piece of polished iron and a piece of marble or limestone: yet if iron be exposed to the action of air and water, it is converted into rust, and in this state is known as ochre; and between ochre and powdered limestone there is little difference of external character; nor would any one unacquainted with chemistry suspect, that ochre was a metallic mineral. The ochre can, however, be easily reconverted into metallic iron: but to convert limestone into a metallic substance is a difficult process,—yet it has been effected; and it is further proved, that all the earths and alkalies are metallic substances combined with oxygen. The metallic nature of the earths being ascertained, we can no longer be surprised that metallic minerals should be found intermixed with earthy minerals in rocks. Iron is found combined with earths in almost all rocks that are not white; and to the presence of iron, they generally owe their colour, whether red, brown, or black.

The other metals rarely occur chemically combined with rocks or strata, but are found either disseminated in grains or irregular pieces, or forming beds between earthy strata, or filling veins that intersect rocks vertically or nearly so.

The metals, except gold and platina, are rarely found pure, but are generally combined either with sulphur, oxygen, or acids, and in this state are called *ores.* When the metals occur pure, they are called *native metals;* thus we have native gold, native iron, &c.

Metallic ores and native metals are sometimes disseminated in grains through rocks; and when they are abundant, the whole mass of the rock is worked as a mine; but this is seldom the case. Tin-stone, or the oxide of tin, is sometimes disseminated in grains in granitic rocks in Cornwall, but it is generally in the vicinity of a vein of tin ore that disseminated grains of tin-stone are found in the rock. At Weal Dutchy mine, near Callington, silver ore is obtained, both from a vein which intersects the hill, and from the rock itself, at a considerable distance from the vein. From a section of the mine shown me by the proprietor, it appears that in the rock, which is white killas (a silvery clay slate,) the ore is disseminated in various parts, or is collected in bunches. The silver is found native in filaments, or in the state of vitreous silver ore, black silver, and ruby silver. Gold frequently occurs in grains, disseminated through solid rocks. Considerable masses of metallic ore are sometimes found in rocks, particularly of iron ore; but these masses are generally formed by the meeting of numerous veins, or are parts of metallic beds that are greatly enlarged: they will be described with beds and veins.

Metallic Beds.—Some metallic ores occur, forming regular strata in the secondary rocks, or beds in transition and primary rocks. Iron-stone in thin strata alternates with coal, coal-shale, and sandstone, and has been described with the coal strata—Chap. VIII. pp. 118, 119.

Iron ore often forms beds of considerable thickness, interposed between rocks of gneiss, mica-slate, and slate. Metallic ores in beds or strata may be regarded as constituent parts of the rocks in which they occur, and must be cotemporaneous with them: the metallic and the earthy minerals have been deposited at the same time, and have probably been separated by chemical affinity during the process of consolidation. Sometimes the metallic matter is intermixed with a bed of slate, or of other rocks, in such abundance, that the whole bed is worked as a metallic ore. When a bed of metallic matter swells out irregularly to a considerable thickness, it forms masses of ore, which sometimes attain the magnitude of small mountains;—such are the mountains of iron ore in Sweden and Norway. Metallic beds are, however, of limited extent; they seldom traverse a whole mountain or mountain range, but they gradually or suddenly become narrow and terminate, or in the miner's language *wedge out*. There are few known beds of metallic ores in England; the principal repositories of metallic matter are in veins. I have however ascertained, that the copper mines formerly wrought in the transition rocks of Cumberland, were beds of copper pyrytes, interposed between the beds of the mountains in which they were found, and not intersecting them like veins. The beds of rock being highly inclined, the thin metallic beds between them have been mistaken for veins. I believe that several metallic repositories in other counties, which have been described as veins, are in reality beds; the distinction between beds and veins not being well understood, they are both called veins by working miners. The manganese mines at Doddiscombe Leigh, in Devonshire, are irregular beds of oxide of manganese in red sandstone. Iron ores, particularly magnetic iron ore, frequently occur in beds. The iron mine at Dannemora in Sweden is an enormous bed, which has swelled out to the thickness of one hundred and eighty feet of nearly compact ore. Copper pyrites sometimes occurs in beds; mercury has also been found disseminated in beds of clay and sandstone. Ores of black oxide of cobalt are found in beds at Alderly Edge in Cheshire.

Metallic veins appear to have been originally fissures cutting through different beds of rock, that have been subsequently filled with metallic ores, intermixed with other mineral matter, of a different nature from that of the rock which is intersected. Metallic veins are therefore considered to be of posterior formation to the rocks in which they are found: and where a vein cuts through different rocks, it is evident that its formation must have been more recent than that of the rocks; but where a vein is found only in one bed of rock, the fissure may have been formed and filled, at the period when the rock was consolidated. Metallic veins are found principally in primary and transition rocks, or in the very lowest of the secondary strata: they are often separated from the rocks they intersect, by a thin wall or lining of mineral substances distinct from the rock, and sometimes also by a layer of clay on each side of the vein. The same substance which forms the outer coat of the vein, is also frequently intermixed with the ore, or forms layers alternating with it: this is called the matrix, gangue, or vein-stone. It appears as if the ore and the vein-stone had been formed over each other, on the sides of the vein, at different times, till they met and filled up the fissure.

Sometimes the ore extends in a compact mass from one side of the vein to the other. Not unfrequently there are hollow spaces in veins, called *druses*, which are lined with crystals. In these cavities the most beautiful and regular crystalline forms are obtained. Metallic veins often divide and unite again, and sometimes they separate into a number of smaller branches, called strings. A general idea of the manner in which metallic veins intersect rocks, and are sometimes intersected by each other, is represented Pl. 4. fig. 5. To what depth metallic veins descend is not known, nor is it ascertained whether they generally grow wider or narrower in their descent. The opinions of miners on this subject are so various, that it may fairly be inferred that they differ in this respect, in different situations. No instances I believe have occurred of a vein being worked out in depth, though it often grows too poor to repay the labour of working deeper: more frequently the further descent of the miner is stopped, by the difficulty of removing the water. Veins are seldom rich in ore near the surface, but increase in richness as they descend, and at greater depths become poorer again. When Pryce wrote the "Mineralogy of Cornwall," it was believed that the richest state of a mine for copper in that county, was from eighty to one hundred yards deep; and for tin, from forty to one hundred and twenty yards. This account by no means agrees with the present state of the Cornish mines. Copper and tin are procured in considerable quantities at the depth of four hundred and fifty-six yards in the Dolcoath mine. The Ecton mine in Staffordshire is now worked at the depth of four hundred and seventy-two yards: it is the deepest mine in England. The deepest mine that has been worked in Europe, or in any part of the world, is one at Truttenberg in Bohemia, which is one thousand yards below the surface.

Metallic veins frequently contain different ores at various depths. Iron ore, copper ore, cobalt ore, and silver ore, succeed each other in some of the mines in Saxony.

In France there are mines which contain copper ore in the lowest part, silver ore above, and over that iron ore.

In Cornwall, blende, a sulphuret of zinc, frequently abounds in the upper part of veins that become rich in copper as they descend, the blende rarely continuing to any considerable depth. In the same district tin is also commonly found at a small depth, in veins which afterwards prove rich in copper. "Among other instances that might be quoted, are the two deep extensive copper mines called Huel Unity, and Cook's Kitchen, both of which were worked for tin at first. In both, the tin was soon extracted; but it should be noted as an uncommon circumstance, that in the latter mine, after working to the depth of one hundred and eighty fathoms, first through tin and afterwards through copper, tin was found again, and has continued down to its present depth of two hundred and ten fathoms from the surface. It ought, however, to be added, that some portion of tin was found in different parts of the vein, which may therefore be said to have prevailed more or less from the surface to the present workings.*

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* Transactions of the Geological Society, vol. ii.

The thickness of veins, and the quantity and quality of the ore they contain, vary in every mine. Some veins are only a few inches wide; others are several feet, and sometimes several yards, in width. Veins are often narrow in one part, and swell out in another. The vein at the Dolcoath mine in Cornwall varies from two or three feet, to forty feet, and in some places it contracts to little more than six inches. The vein-stone is quartz, in which are imbedded masses called bunches of copper pyrites, consisting of copper united with sulphur.

Beside rake veins, there other mineral repositories, called flat veins, or flat works and pipe veins. In some instances a rake vein declines from its regular inclination, and has taken the direction of the beds or strata for a greater or less extent, and then resumes its former inclination. In other instances the cavities between beds or strata are filled with metallic ores, lying between an upper and lower stratum, like a seam of coal, and are subject to similar dislocations: but these are not regular strata; they may frequently be traced to a perpendicular or rake vein, from which they appear to be lateral expansions; see Plate 7. fig. 2. There is generally what is called a rider, or mass of mineral matter between the ore of very strong rake veins, and that in the flat veins, at the place of junction. The flat veins that run parallel between the strata, frequently open into large cavities filled with ore and vein-stone: these cavities close again by the contracting, or what the miners call twitching of the sides, by which the ore is nearly or totally excluded. Such expansions and twitchings are also common to rake veins, and are represented at *c c*, Plate 4. fig. 4.

The blue john or fluor spar mine near Castleton is of this kind. The vein which contains this spar is separated from the limestone rock by a lining of cawk or sulphate of barytes, and by a thin layer of unctuous clay; it swells out into large cavities, which contract again and entirely exclude the ore, leaving nothing but the lining of the vein to conduct the miner to another repository of the spar. The crystallizations and mineral incrustations on the roof and sides of the natural caverns which are passed through in this mine, far exceed in beauty those of any other cavern in England; and were the descriptions of the Grotto of Antiparos translated into the simple language of truth, I am inclined to believe, it would be found inferior in magnificence and splendour of mineral decoration, to the natural caverns in the fluor mine. This mine is rarely visited by travellers: the descent is safe, but the roof being low in some parts it is rather difficult of access.

The pipe vein may be described as a tubular mass of ore and vein-stone, generally descending in the direction of the beds, and widening and contracting in its course. In reality, the pipe vein is a variety of the flat vein, having the sides closed or twitched in, so as to form a tube or cavity of irregular shape, and of very limited extent along the line of bearing, but descending to a great depth.

One metallic vein often crosses or cuts through another, and displaces it; in such instances it is evident that the vein which is cut through, must be more ancient than that which intersects it. This observation respecting the relative ages of veins was first made by Mr. Pryce in his *Mineralogia Cornubiensis*. The different position of veins is represented in Plate 4. fig. 4, where *a a* is a vein intersecting a rock; it divides in part of its course and unites again, and finally branches off into small strings. In many instances these strings lead to a further continuation of the vein; perhaps this would be found to be the case in all, were the workings carried on in the same direction. *b b* is another vein which cuts through the former, and has thrown the lower part of the vein *a* out of its course. Sometimes one vein passes through another without changing its direction. When one vein crosses another which has an opposite inclination, it is observed that they often become poorer; but when two veins which have the same general inclination unite, they are most frequently very rich in ore at the junction; (Plate 7. fig. 4. *a* and *b*;) and when a number of veins cross each other at one place, they sometimes form a cone or mass of ore of prodigious size, widening as it descends. Such are called accumulated veins. They occur in the mining district of Durham and Northumberland, in the metalliferous limestone. The excavation formed when the ore is worked out resembles in shape the inside of a large glass furnace. The masses of ore formed by the junction of numerous veins converging to one place, are very different from the masses of ore formed by the swelling out of one metallic bed before described.

The direction of rake veins is not very regular. In England, the principal veins generally run nearly east and west, and north-east and south-west; but have frequently undulations and deviations from a straight line: the most powerful veins are more regular in their course than smaller ones. Where two veins in the same district have the same direction, or run parallel, it is observed that their contents are similar; but where they run in different directions, the contents vary. Molina, in his interesting History of Chili, mentions a vein of silver at Uspalata, in the Andes, which is nine feet in thickness throughout its whole extent, and has been traced ninety miles. Smaller veins branch off from each side of it, and penetrate the neighbouring mountains to the distance of thirty miles. It is believed that this vein stretches to the distance of three hundred miles. A vein called the Tidswell Rake, in Derbyshire, extends some miles east and west; it is worked from the surface, and may be seen near the road side, between Great Hucklow and Tidswell. I was informed in Cornwall, that no vein in that country had been traced in length more than two miles; nor had any vein been worked out in depth: the common width of the veins is from one to two feet, but sometimes it exceeds thirty feet.

In Cornwall and Devonshire, and in the mines of Northumberland and Durham, the principal metallic veins range nearly east and west. In the former counties they are called *lodes*, in the latter *right running veins*. The north and south veins which intersect them are called cross courses; these are seldom productive of ore. The thin cross courses filled with clay are called *fluan*. I was informed by an intelligent proprietor of mines in Cornwall, that these thin cross courses invariably displace the veins, and hold up the water on one side of the vein; but it is most worthy of notice, that a vein which is rich in ore on one side of the fluan, will be poor on the other. Query, *Is this connected with the fluan holding up the water?* In Cornwall the cross courses displace the east and west veins; the displacement is only a few inches in some veins, in others it is several fathoms. On Alston Moor in Cumberland, a large cross course called Old Carr's cross vein, cuts through two veins called Goodham Gill vein and Grass Field hill vein, and has thrown them aside about fifteen or twenty fathoms. When the cross course intersects the east and west veins at right angles, the displacement is generally less, than when it strikes it in an oblique direction. This effect will be more clearly conceived by referring to Plate 7. fig. 3. which is supposed to represent a ground plan of the principal veins intersected by a cross course.

In Northumberland and Durham, cross courses contain ore, near their junction with powerful veins. In Cornwall, ores of silver and cobalt have been found in some of the cross courses; and at the Botallack mine, north of the Land's End, a powerful cross course, running north and south, is made rich by the junction of east veins, which resemble small rivulets, opening into a river. Their position will be better understood by referring to Plate 7. fig. 6. The direction of the cross course or great vein running north and south, is represented by the letters N. S. the direction of the small veins, rich in ore, which open into it, are represented by *e e e*. The cross course is rich in ore, to the distance of twenty or thirty fathoms, on each side of its junction with a vein; but no veins are found branching from the west side of the cross course. The cross course is worked in those parts, where it is rendered rich by the junction with veins; the small veins are also worked for ore, and are very productive. The rock is what is called a free or soft killas, near the great cross course or vein; but further from it, it becomes a hard blue Elvan flinty slate. The width of the vein varies from nine to twelve feet. It contains gray copper ore of a rich quality. Sometimes the sides of the vein are copper ore, and the middle is tin ore, as represented Plate 7. fig. 7, which is a vertical section of part of the vein; fig. 6. is an horizontal section. The master of the mine furnished me with the above particulars; and under his direction, I made, on the spot, the two rough sections, which will serve to convey a better notion of this singular metallic repository, than can be obtained by a verbal description.

Nor should it be omitted, that the entrance of this mine is at the foot of a precipice more than two hundred feet in height, on the border of the Atlantic Ocean, and the workings of the mine extend two hundred and thirty yards under the sea. From this submarine recess, I saw rise up, one of the best-formed and noblest-looking men I ever beheld, a perfect model for the Apollo of a sculptor.

Particular metallic ores are peculiar to certain rocks. Thus, tin-ore occurs in granite and some kinds of slate, but has never been found in limestone. Certain ores are not unfrequently associated together: thus lead and zinc often occur in the same vein, but in different proportions. The same metal in various combinations is often found in one vein: thus native copper, sulphuret of copper, carbonate of copper or malachite, sulphate of copper or blue vitriol, and copper combined with lead and iron, frequently occur together in the same mine.

Galena, a sulphuret of lead, is often associated with white lead ore, or carbonate of lead. The latter, though a rich ore containing seventy per cent of lead, has no metallic appearance, and was mistaken for cawk, and thrown away, by the miners in Derbyshire, until the year 1803 or 1804. The mines of that county have been worked ever since the time of the Emperor Adrian, and the quantity of ore which has been wasted during that period must have been immense.*

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* In 1810 few of the working miners could distinguish compact white lead ore, from cawk or sulphate of barytes; their specific gravity and appearance are not very different. The following test is of easy application, and will serve to discover the presence of lead:—If a small quantity of flowers of sulphur, mixt with a little potash or soda, be melted on the point of a knife, in a candle, and applied to the moistened surface of the stone, it will make a black spot if the mineral contain white lead ore.

In what manner metallic veins were filled with ore has greatly divided the opinions of geologists. Dr. Hutton supposes that both dykes and veins were filled with their contents in a state of fusion by injection from below, the expansive force of the melted matter having cracked the surface, and opened a passage for its reception. That many dykes were so formed I think probable, from circumstances previously stated. Other dykes appear to have been open fissures filled by materials washed from the surface, and contain rounded stones and sometimes undecayed vegetable matter. From a dyke of clay in a coal mine in Yorkshire, two hundred and fifteen feet deep, I have drawn out long vegetable fibres, apparently roots; the woody part of which was unchanged, and burned like the roots of common weeds. Werner supposes all veins and dykes were first produced by the shrinking of the materials of which mountains are composed; and that metallic veins have been filled from above by the ores in a state of solution. This theory has been advanced with much confidence, and warmly supported by many geologists: but I have no hesitation in asserting, that it is demonstratively repugnant to facts: indeed, the implicit credit which has been given to Werner's dogmas on this subject, is one, among numerous instances, of men of distinguished talents resigning their judgment to authority, and supporting the most absurd propositions, when conformable to their favourite hypotheses. If veins were filled by metallic solutions from above, these solutions must have covered the highest mountains over the whole earth; and instead of finding metallic ores in the present confined repositories, they would fill all the cavities and valleys in every part of the world. As this theory supposes likewise that veins were formed at different times, a number of these metallic solutions would succeed each other, and we should find regular strata of ore in all primary and transition rocks; and the quantity formed by these deep seas of metallic matter would be inconceivably great.*

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* Metallic ores may, in some instances, have been formed in fissures which were once open at the top, or veins may have been re-opened by a subsequent convulsion. The round pebbles which are sometimes found in veins, prove that there must in such instances have been a connection with the surface.

This theory is decidedly invalidated by the following facts. When a metallic vein passes through different kinds of rock, it is generally observed that the quality of the ore varies with that of the rock through which it passes; and even different beds of the same rock are more productive than others, and are called by miners *bearing measures*. This is the case in Durham, Derbyshire, Cornwall, and probably in every mining district in England and Wales.

Not only does the variation in the nature of the rock occasion a change in the quantity or quality of the ore, but the mineral substance or matrix which accompanies ores, generally varies in different kinds of rock. Quartz and barytes are more frequent in granite and slate rocks, than calcareous spar. In calcareous mountains, quartz is more rarely the prevailing matrix. In the counties of Durham and Northumberland, veins pass through siliceous sandstone, argillaceous shale, and limestone. See Plate 7. fig. 2. The ore is more abundant in the limestone than in the sandstone, and in the shale provincially called *plate*, ore very rarely if ever occurs. In one mine at Welhope, the matrix of the vein, as it passes through the sandstone, is cawk or the sulphate of barytes; but when it enters the limestone, it changes to carbonate of barytes in balls, having a radiated diverging structure. But what is still more deserving of notice, when the rock on one side of a vein is thrown up or down considerably, so as to bring a stratum of limestone opposite a stratum of sandstone, or when what are called the walls or cheeks of the vein are of two different kinds of stone, (see Plate 7. fig. 5.) the vein is never so productive in ore, as when both sides of the vein are of the same kind. This fact alone seems sufficient to invalidate the theory of Werner, that veins were filled with metallic solutions poured in from the upper part. Had this been the case, the nature of the rock could have made no difference in the quality or quantity of the ore.

Werner in his Treatise of Veins, states one instance, as if it were extraordinary, of the ore changing its quality, as the vein passed through different rocks; and is inclined to admit that elective affinity for the rock, may have contributed to the effect. The circumstance, so far from being extraordinary, is of common occurrence, and known to all working miners. The entire cessation of the ore in one part of a rock, and its re-appearance below, are still more striking.

In Derbyshire, the beds of metalliferous limestone are separated by beds of basaltic rock, called toadstone.* When a vein of lead is worked through the first limestone down to the toadstone, it ceases to contain any ore, and often entirely disappears: on sinking through the toadstone to the second limestone, the ore is found again, but is cut off by a lower bed of toadstone, under which it appears again in the third limestone. In strong veins, particles of lead occur in the toadstone, but in very small quantities.

If mineral veins were filled from above by metallic solutions, it is impossible to conceive that the nature of the rock should change the quality of the ore; much less could the ore disappear in one stratum, and appear again in a stratum below it. Nor could the vein be filled with melted matter ejected from below; for in either case it would be equally impossible to explain why the ore is separated by the toadstone, though the vein is continued through it. See Plate 4. fig. 5, where *b b b* are three beds of limestone divided by beds of toadstone *e e*, and covered by sandstone. When the vein descends to the first bed of toadstone *e*, it entirely disappears; but on sinking through to the second bed of limestone *b*, the vein is found again; it disappears a second time at the next bed of toadstone, and reappears in the lower limestone. Another vein, *a a*, is supposed to penetrate the beds of toadstone *e e*, but contains no ore where it passes through them. The upper part of the vein *a* is represented as penetrating the superincumbent sandstone, which is sometimes the case: in this part of the vein the most curious productions of the Odin mine near Castleton are discovered. In some situations, where the beds of limestone are divided by seams of clay provincially called way-boards, these way-boards cut off the vein as effectually as the toadstone. Such facts prove that these veins were not filled from above. Professor Jameson has conjectured that the beds of toadstone and limestone in Derbyshire, with the metallic veins, were all cotemporaneous, and that the toadstone crossed through the veins, at the time of their formation; but the different organic remains in the upper and lower beds of limestone preclude the possibility of their having been formed at the same time. The zoophytes in the lower bed of rock could not be living and co-existent with the shell-fish in the upper, nor with the vegetable remains occasionally found in the sandstone which frequently covers the whole, and into which the veins sometimes shoot. Cuvier has well observed, that the existence of different organic remains offers incontestable proofs, that the upper and lower strata in which they were found, were formed in succession.

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* The fact of metallic veins being entirely cut off by the beds of toadstone, has recently been doubted; it is supposed that the vein is continued through the toadstone, though it contains no ore: but the fact of veins being cut off by the seams of clay between the strata (called way-boards) has not been denied, that I know of. The last time I was in Derbyshire, I endeavored, but in vain, to obtain correct information respecting the veins being entirely cut through by the toadstone. There is, at the present time, a vein working in what is called toadstone, above the village of Matlock; but the stone is a softish green argillaceous stone, intermixed with limestone. If the way-boards of clay cut through the metallic veins, the conclusions to be drawn from the fact, are the same as if they were cut through by toadstone. I have therefore left the description of the Derbyshire veins unaltered from the former edition.

If metallic matter were not poured in from above, nor ejected from below, in what manner did it come into the vein?—The state of chemical science, and the facts at present known, are too limited to furnish a solution to this interesting question. There are, however, certain indications which may serve as a clue to future discovery. The variation of the mineral products in veins as they pass through different strata, seems to prove that the strata were efficient causes in producing this variation. Perhaps metallic matter was diffused through different rocks according to their elective affinity, and separated from them by voltaic electricity, the different sides of the vein possessing different states of electricity; or the strata may act like a series of plates in the voltaic pile, separating and secreting metallic matter from its different combinations. Some of the metals and other substances found in veins, are capable of solution in hydrogen gas, and perhaps all of them may be so by natural processes; in this state they may have penetrated the vein and deposited their contents.

The discovery of the metallic nature of the very earths of which rocks are composed, and the probability that the metals themselves are compound substances, of which hydrogen forms a part, open new views respecting the formation of metallic matter by natural processes, which may be within the reach of human power to develop, if not to imitate.

If metallic matter be now forming in mines, the process of its formation is extremely slow; but there are circumstances which appear to prove that it may in some instances be perceived. Mr. Trebra, director of the mines in Hanover, informed a gentleman of my acquaintance, that he had seen a leather thong suspended from the roof of a mine, coated with silver ore: he has also observed native silver and vitreous silver ore coating the wooden supports left in a mine called Dreyweiber, in the district of Marienburgh, which had been under water two hundred years, and was opened in 1777.

Mr. Trebra was led from his own observations on mines to infer, that metallic ores are formed by mineral exhalations, or were once in a gaseous state. Mr. Westgarth Forster, a practical miner in Northumberland, states, that at Wolfclough mine, in the county of Durham, which was closed for more than twenty years, and opened again, needles of white lead ore were observed projecting from the walls, more than two inches in length.

These and other phenomena observable in mines, may convince us that there are processes going on at present in the great laboratory of the earth, and perhaps there are analogous processes taking place in the atmosphere, which may throw some light on these hidden operations of nature. The formation of saline matter on the surface of walls, is a fact which merits more attention than it has hitherto received. Dr. Kidd, of Oxford, has published some very ingenious observations and experiments on the spontaneous production of nitre on limestone, which may lead to more important results than the learned Professor appears to have anticipated. These experiments show, that neither the alkali nor the acid exists previously in the stone. Nor do they exist ready formed in the moisture of the atmosphere, dry frosty weather being particularly favorable to the rapid production of nitre, and moist weather the contrary.

When a portion of the wall was protected from access to the atmosphere by glass, which projected a little distance from the surface, the formation of nitre went on for a certain time and then ceased. The saline crystals were better defined and longer than on the other parts of the wall. When the wall was coated with with paint, crystals of nitre were even formed on the paint. The formation of carbonate of lead on the walls of the mine at Wolfclough may be analogous to the formation of nitre; and in both instances, the surface of the wall and of the atmosphere, may perhaps be considered as two galvanic plates in action, decomposing and recompounding the elements of metallic or saline matter from the atmosphere, or the gaseous fluids with which it is intermixed. The base of nitre (potassium) is known to be a metal; and could we seize nature in the act of producing a fixed alkali from more simple elements, we might compel her to reveal the process by which she prepares her metallic treasures in the deep recesses of the earth. Nor can the discovery be very remote; for we are already acquainted with the composition of the volatile alkali, and are thereby enabled successfully to imitate nature in its formation.

When the matrix, or the substance which principally fills veins, is a soft unctuous clay, masses and particles of ore are often disseminated through it, varying in size from a pea to that of a large gourd, and are sometimes even of many tons weight. Masses of vein-stone are also imbedded in the same manner; and it is observed that the masses both of ore and vein-stone are of no determinate shape, and have generally the appearance of being corroded. Are we to conclude in such instances, that the hard minerals and metallic ores, have been formed in the substance of the clay by some peculiar elective affinity, or that they once occupied the cavity of the vein, and have been all subsequently decomposed, except the remaining detached masses? I should be more inclined to adopt the former opinion; but it must be allowed, that there are inexplicable instances of the disappearance of minerals which formerly existed in veins.

The formation of one mineral upon the crystals of another, and the disappearance of the crystal which has served as the mould, is indeed a common phenomenon in many English mines. I have before me a mass of rock crystal from Durham, formed on cubic fluor spar; but the crystals of the latter have entirely disappeared, leaving nothing but the impression of their form. In the mines of Derbyshire, incrustations of calamine are formed on calcareous crystals, taking the shape of the dog-tooth spar; but in these false crystals, no trace of the interior crystal is left. Certain local causes also appear to influence the crystallization of minerals in different districts, and dispose them to take peculiar secondary forms, which may be considered as appropriate to the minerals of that district. The pyramidal crystallization of carbonate of lime, called the dog-tooth spar, (*Chaux carbonatée metastatique* of Haüy,) is abundant in some of the mines of Derbyshire; whilst the same mineral rarely assumes that form in the mines of Northumberland and Durham, but is crystallized in other forms, which are equally rare in the Derbyshire mines. Fluor spar, and barytes spar, have appropriate forms in different districts, from which any deviations may be considered as varieties. The causes which occasion this diversity of secondary forms in minerals, whose constituent parts appear by chemical analysis to be precisely the same, are unknown; nor are we able to explain in what manner the crystals before mentioned have disappeared: but these facts prove, that the powers of nature extend beyond the present limits of science; and it is more consonant with the true spirit of philosophy frankly to acknowledge our ignorance, than to form systems from imperfect data, which can serve only to perpetuate error.

Metallic ores in rounded fragments, and grains of native metals, are frequently found in the sands of rivers; they have been carried there by torrents or inundations; the rocks in which they were originally formed, having been disintegrated or decomposed. The metals gold, and platina, being indestructible by the action of air, water, or the mineral acids, remain for ages unchanged, in the form of minute grains. The oxide of tin is a very heavy and hard mineral; and it is owing to its weight and indestructibility, that it is found in the sands of rivers, or on the sea shore, where it sometimes occurs in considerable quantities, and is separated from the sand or alluvial soil, by directing streams of water over it; hence such works are in Cornwall called Stream Works. With the pebbles of tin-stone, there are fragments of granite and other rocks, which serve to indicate from what mountains in the vicinity the stream tin has been washed out. Particles and small pieces of gold are sometimes found with stream tin, in the sands of Cornwall.

Mr. Hennah, of Plymouth, has in his collection several pieces of native gold, varying from the size of a bean to that of a hazelnut; they were found in stream works near St. Austel: he has also a specimen of stream tin, eight or nine inches in length, and five or six in breadth, which was evidently once part of a vein. In the same stream work they could distinguish at different depths, the different veins from which the ore had been washed out. The pebbles of tin ore, have in some situations been washed into the sea, and afterwards covered by beds of clay or gravel. In Mount's Bay, south of the town of Penzance, there was formerly a bed of stream tin worked under the sea. The stream tin covers the killas or slate rock of the country, and is covered by a bed of clay: a perpendicular shaft or tunnel was sunk through the clay, and the bed of stream tin was worked like a bed of coal, the clay forming the roof. See Plate 7, fig. 8. The workings were continued under the sea, but were at length inundated and discontinued.

The following is a summary account of the rocks and situations in which the different metallic ores are generally found:

Platina and the recently discovered metals called palladium, rhodium, osmium, and iridium, have been found only in the sands of rivers.

Gold and silver are found in primary and transition rocks, in porphyry and sienite, and in the lowest sandstone. Gold has been occasionally discovered in coal, and very abundantly in the sands of rivers, and sometimes in volcanic rocks.

Mercury is found in slate, in limestone, and in coal strata.

Copper in primary and transition rocks, in porphyry, sienite, and occasionally in sandstone, in coal strata, and alluvial ground. Masses of native copper of many thousand pounds weight, are said to be found on the surface in the interior of North America.

Iron, in every kind of rock.

Tin, in granite, gneiss, mica-slate, and slate.

Lead and zinc, in primary and transition rocks, except trap and serpentine; in porphyry and sienite; in the lowest sandstone, and occasionally in coal strata.

Antimony, in primary and transition mountains, except trap and serpentine; it is also found in porphyry and sienite.

Nickel, bismuth, cobalt, in primary mountains, except limestone, trap, and serpentine. Cobalt and nickel also occur in transition mountains, and in sandstone.

Arsenic, in primary and transition mountains, and in porphyry.

Manganese, in primary and transition mountains, and occasionally in the lower stratified rocks.

Molybdena and tungsten, uranium and titanium, in granite, gneiss, mica-slate, and slate. The latter metals, with chromium, columbium, cerium, and tellurium, are very rare in nature, and can be reduced to the metallic state only with great difficulty.

CHAPTER XVIII.

ON THE DESTRUCTION OF MOUNTAINS.—ALLUVIAL AND DILUVIAL DEPOSITIONS.—THE FORMATION OF SOILS.—AND ON THE BONES OF QUADRUPEDS IN BEDS OF GRAVEL AND CLAY, AND IN CAVERNS.

Proofs of the Disintegration of Rocks.—The rapid destruction of Mountains dependent on their Structure.—The Fall of Mont Grenier and other Mountains in the Alps.—The breaking down of the Barriers of Mountain Lakes.—Masses of Rock scattered over Valleys and Hills.—On the Increase and Decrease of Continents and Islands, and the Formation of productive Soils.—Recent Strata formed in Lakes.—Peat and Peat Moors.—Human Bodies preserved in Peat.—Inundations of Sand.—Coral Islands.—The Remains of Land Quadrupeds found in Bogs, in Beds of Clay or Gravel, and in Caverns.

The disintegration of rocks and mountains is constantly taking place by the incessant operation of the elements; all bare and lofty cliffs and eminences are gradually wearing down; and the process will go on, until they are covered with soil and vegetation, which protect them from further decay. Beside the causes which at present operate to reduce the most exposed and prominent parts of the earth's surface, and transport their materials into plains, or to the sea shore, there are evident indications of the destructive effects of ancient inundations, which have swept over the surface of the present continents, have excavated new valleys, torn off the summits of the loftiest mountains, and spread their ruins in immense fragments over distant regions. The sand, soil, or fragments, brought down by rivers, and spread along their banks or at their mouths, are called *alluvial depositions.* The blocks of rock, and the beds of gravel spread or scattered on the surface of the ground, composed of stone or fragments foreign to the district in which they are spread, and which frequently cover the bones of unknown species of quadrupeds, are called *diluvial depositions*, viz. depositions which have been formed by a deluge. We shall first consider the causes which are at present wearing down the surface of islands and continents: these are sometimes adequate to produce the most tremendous effects, and to overthrow mountain masses of immense magnitude. By considering these effects, we shall be better prepared to admit the mighty action of diluvial agency in remote epochs. Indeed it is not always easy, to distinguish with certainty the effects of alluvial from diluvial agency. We have, however, incontestible evidence, that the disintegration of mountains has been effected by both causes.

Instances have occurred in our own times of mountains suddenly falling down, and burying the inhabitants of the vales below, under their ruins. In the Alps, the process of disintegration is rapidly going on; but such is the immensity of these enormous mountains, that ages pass away, before any diminution of their bulk is perceived.

According to the account of Patrin, who had travelled in Northern Asia, the whole of that country is covered to the depth of many hundred feet by innumerable beds of micaceous and argillaceous sand, washed down by inundations from the high range of mountains in the interior of Asia, and carried as far as Siberia. The deserts of Arabia are also covered with alluvial or diluvial depositions. C. Leckie, Esq. informed me, that between Hit and Tahiba, the soil is composed of sand and gravel, on which may be seen small volute and bivalve shells; but the sand is not loose like that in the deserts of Libya.

That the mountains of our island have once been much higher than at present, is evident to every one who has attentively examined them. The rocky fragments in Borrowdale, the deep ravines made by torrents in the sides of Skiddaw, the immense blocks of granite from Westdale Craig in Westmoreland, scattered over the neighbouring counties, offer striking proofs of this. The central parts of England have also once had a greater elevation. The white quartz pebbles and fragments of quartz rock, sienite and flinty slate, spread over the midland counties, are the remains of the decomposed hills in Charnwood Forest, and of others once connected with them, which are now worn down

Beds of flint-gravel, are formed by the disintegration of chalk rocks, in which flints are imbedded, as may be seen on the sea shore under chalk cliffs; but beds of flint-gravel, are also spread over many parts of England distant from chalk rocks, and at a considerable elevation above the level of the sea. Hence we have evidence that chalk rocks once covered a larger portion of England than at present. It is however in the vicinity of the Alps that the disintegrating effects of the elements, and those of diluvial agency, are most strikingly displayed. Innumerable blocks of primary rocks torn from the central range of mountains, are spread over the calcareous mountains, and in the valleys, to the distance of one hundred miles or more from their native beds. Blocks of great size are also found immediately under the mountains from whence they have fallen, or scattered over the surface of glaciers; and as the lower parts of the glaciers are gradually melting, the upper parts progressively move down into the valleys, and deposit the fragments in heaps at their feet:—these depositions of stone are called *morains*. The destruction of granitic and schistose mountains, that are divided by nearly vertical seams or partings, is often rapidly effected; water, insinuating itself into the interstices or seams, becomes expanded by frost, and tears down great masses of rock, with a sudden explosion like that of gunpowder. The overthrow of calcareous rocks is effected in a different manner, and the vast *eboulements* which they occasion, are more terrific and destructive than the eboulements from the primary mountains, as they generally take place in more thickly inhabited districts.

The destruction of the calcareous mountains in the Alps, depends on the peculiar composition and structure of these mountains. In the year 1821, I passed a great part of the summer in examining the calcareous mountains in Savoy; the structure of which was then not understood, or at least had not been described in any geological work that I had met with. It was generally believed that the calcareous mountains were composed entirely of beds of limestone, with lofty mural precipices on the upper part; and that the lower parts, sloping from these precipices, were formed of the debris of the limestone. So far from this being the case, the calcareous mountains of the Alps, which comprise all the English formations, from the magnesian limestone to chalk, alternate like the English formations, with enormous beds of shale and soft sandstone; and it is to this alternation, they owe the frequent destruction of the upper parts of the mountains.

If all our English secondary formations were by some powerful cause elevated six or seven thousand feet above their present level, and the beds bent into curves constituting several ranges of mountains, we should have precisely what is found in the calcareous ranges of the Alps. This arched form of the calcareous mountains is represented Plate 2. fig. 1. and fig. 2. *x y*. Now if one thick bed of limestone, or a portion of it, be broken off as at *z*, fig. 2. the action of continued rains on the soft beds on which it rests, will undermine it, until other portions of the limestone will fall down; and if this process take place on both sides of the mountain, the whole of the bed of limestone will fall, except the part which rests flat upon the summit: and in this manner have been left the enormous caps of limestone, like immense castles, that compose the summits of the calcareous mountains, near the lake of Annecy, and the Bauges. Sometimes when the mountains are seen in profile, the caps which form an extended range in front, present the appearance of a narrow ridge when seen in profile.

The mountain called the Dent d'Alençon, near the Lake of Annecy, offers a remarkable instance of this. See Plate 2. fig. 6. The mass of limestone on its summit,—which I found by trigonometrical measurement to rise three thousand eight hundred and forty feet above the lake, and to be nearly five hundred feet in thickness,—was undoubtedly once a continuous bed, covering the mountain like a mantle, as represented by the dotted lines; in the course of ages, the side *a a*, has fallen down, and the steep escarpment on the other side at *b*, is at present undermining, by the action of rain on the soft bed *c c*, and preparing for a further disintegration. The soft bed *c c*, which forms the talus or slope, being partly covered with vegetation on the side *b c*, is in some parts protected from rapid disintegration. On the opposite side of the valley, I found that the thick bed, which formed the talus or slope under the limestone, was lias clay. I was not able to ascend the Dent d'Alençon, and therefore did not ascertain whether the bed *c* was soft sandstone or lias. In numerous instances, the upper beds of limestone in the mountains of Savoy may be observed overlapping and overhanging, as at *a a*, Plate 3. fig. 1, and are thus prepared to fall, whenever the rain and frost has widened the longitudinal natural fissures in the limestone. The present state of Mont Grenier, south of Chambery, and the vast ruins in the plain below, offer a striking illustration of the causes which are in operation, to disintegrate the vast calcareous mountains of Savoy.—The following description is copied from the 1st volume of my Travels. "A part of Mont Grenier fell down in the year 1248, and entirely buried five parishes, and the town and church of St. André. The ruins spread over an extent of about nine square miles, and are called *les Alymes de Myans*. After a lapse of so many centuries, they still present a singular scene of desolation. The catastrophe must have been most awful when seen from the vicinity; for Mont Grenier is almost isolated, advancing into a broad plain, which extends to the valley of the Isère. It is several miles in length, and is connected with the mountains of the Grand Chartreux, but it is very narrow. Its longitudinal direction is from east to west: near the middle it makes a bend towards the north, forming a kind of bay or concavity on the southern side."

"Mont Grenier rises very abruptly upwards of four thousand feet above the plain. It is capped with an immense mass of limestone strata, not less than six hundred feet in thickness, which presents on every side the appearance of a wall. The strata dip gently to the side which fell into the plain. This mass of limestone rests on a foundation of softer strata, probably molasse; under which are distinctly seen thin strata, alternating with soft strata. The annexed cut represents the east wing of the mountain and a small part of the Alymes de Myans. There

can be little doubt that the catastrophe was caused by the gradual erosion of the soft strata, which undermined the mass of limestone above, and projected it into the plain. It is also probable, that the part which fell, had for some time been nearly detached from the mountain by a shrinking of the southern side; as there is at present a rent at this end, upwards of two thousand feet deep, which seems to have cut off a large section from the eastern end, that now

> 'Hangs in doubtful ruins round its base.'

as if prepared to renew the catastrophe of 1248. The Alymes de Myans are hills, or rather monticules of a conical shape, varying in height from twenty to thirty feet; they cover about nine square miles; the monticules are composed of fragments of calcareous strata, some of which are of immense size. They consist of yellowish oolitic limestone, strongly resembling the lower oolites in Gloucestershire; a gray limestone, harder and more crystalline than lias, which however it may probably be; a thin slaty arenaceous limestone, much resembling Stonesfield slate. Fragments of schistose chert, were interstratified with some of the limestone."

"The largest masses have evidently fallen from the upper bed of limestone by which Mont Grenier is capped. The velocity they would acquire by falling from so great a height, making due allowance for the resistance of the atmosphere, could not be less than three hundred feet per second; and the projectile force they gained by striking against the base of the mountain, or against each other, has spread them far into the plain. In the course of years, the rains or currents of water from dissolving snows, have furrowed channels between the larger masses of stone, and washing away part of the loose earth, have left the immense number of detached conical hills which are seen at present. So deep and vast was the mass of ruins that covered the town of St. André and the other parishes, that nothing belonging to them has been discovered, except a small bronze statue." (Vol. i. p. 201.)

A part of a mountain near Servos on the road to Chamouny fell down in the year 1751. The fall continued for many days, and the air was darkened with immense volumes of black dust, which extended for twenty miles, and is still remembered by some of the oldest inhabitants of Chamouny. A continued succession of reports, like those of cannon, announced the successive falling of rocks, day and night. The mountain did not, like that of Mont Grenier, fall at once; for it is composed of a succession of beds of limestone resting on sandstone, and extremely fragile schist, which are even now yielding to the constant action of rain. A deep excavation under a precipice of limestone near the summit, appeared in 1821 to threaten a renewal of the catastrophe of 1751.[*]

In the Swiss Alps, the great *eboulements*[†] which have destroyed whole villages, have been caused by the sliding down of highly inclined beds of loose conglomerates, which have been undermined at their bases. This will be better understood by referring to Plate 2. fig. 2. If a bed of conglomerate, *b*, as is frequently the case in the Swiss Alps, forms the outer side of a mountain, uncovered by any harder stratum, the action of rains upon its base, tends to destroy and undermine it, and the whole bed, perhaps several hundred feet in thickness, is suddenly precipitated into the valley. In 1806, a part of the mountain of Rosberg, between the lakes of Zug and Laworts, fell down, from the cause here mentioned, and buried a considerable part of the valley, and several of the inhabitants.

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[*] In an Essay *sur les Caractères Zoologiques*, by M. Brongniart, published in 1822, he has given a section of this mountain; and from the fossils in the upper bed, and the green sand intermixed, he has with much probability classed it with the chalk formation. The lower beds of the mountain, containing ammonites, he still classes with transition rocks; but I am persuaded that these lower beds are not more ancient than the English lias, or the blue beds of the magnesian limestone; and in this mountain, Montagne de Fis, we have all the upper secondary strata of this part of Savoy in one group.

[†] The fall of parts of mountains is so common an occurrence in the Alps, that it is expressively called an *eboulement*, from the verb *ebouler*. In Devonshire and Dorsetshire, the fall of the cliffs is called a *rougement*.

Where the soil is favourable to vegetation, the debris or ruins from the fall of mountains, become covered with vineyards and chesnut trees; of which we have an example in the soil that covers the former town of Pleurs, near Chavennes, and all its noble palaces, belonging to opulent citizens of Milan. On the 26th of August, 1618, "an inhabitant entered the town and said that he saw the mountains cleaving: he was laughed at for his pains; but in the evening the mountain fell and buried the town and all its inhabitants. The number destroyed is stated to be two thousand four hundred and thirty, of whom not one escaped, except the person who warned them of their danger."

Where the soil is unfavourable to vegetation, the ruins remain exposed to the action of rains, and of torrents from the sudden melting of snow, which furrow channels through them, and leave detached monticules, as in the *Alymes de Myans;* but it is evident, that by these causes they could not be transported to distant countries, except in the comminuted form of sand or mud.

There are, however, other causes in present activity, which tear down large masses of rock, and carry them many miles from their native sites. The mountain valleys in the higher Alps, on the confines of eternal snow, sometimes become closed by the extension of a lateral glacier across them, which dams in the water from the melting of Alpine snow, and forms a mountain lake, elevated many thousand feet above the lower habitable valleys. During very hot summers, the same cause which increases the waters in the lake, by a more rapid melting of the Alpine snows, diminishes the strength and thickness of the barrier of ice; it is rent asunder, and the whole water of the lake is suddenly precipitated into the lower valleys with tremendous violence, tearing down and bearing along with it all opposing obstacles: the water is seen approaching like a moving wall. In this manner was the village of Martigny in the Valais nearly destroyed in 1818. A similar inundation, in the valley of the Upper Doron in the Tarentaise, took place in the following year. I had an opportunity of observing its effects, which appeared to equal in intensity, but not in extent, those of diluvial action. Numerous blocks of rock of vast size, were brought down by the torrent, and scattered over a small plain at the mouth of the lateral valley, along which they had descended. These blocks were chiefly quartz rock, intermixed with a few blocks of mica and talc slate.

This group of rocky masses, brought down by a mountain inundation in our own times, renders it probable, that the detached blocks and groups of rocky fragments, spread over many parts of the valley of Geneva, and the sides of the adjacent mountains, may have been brought there by similar causes. The groups often consist of one kind of rock with little intermixture; in other parts, fragments of different rocks are intermixed in the same group. They all have been transported from the central range of the Alps, at a distance of from fifty to one hundred miles or more, from the places where they are now lying. The circumstance which most strongly arrests our notice, is the vast size of these blocks, and the height at which they are found.

On the Great Saleve near Geneva, there is one block of granite seven feet in length, at the height of 2500 feet above the valley: some blocks on the south side of the valley, are at the height of 3000 feet above it. In a wood between Copey and Nyon, there is one block of hornstone seventy feet in length. These blocks lie upon the surface of the ground, and are never found in the subjacent strata. But the most remarkable fact, is that of their occurrence on the northern side of the Jura; they must therefore have been carried over that lofty range. The action of mountain inundations, however great, seems inadequate to produce such effects;—*but is it not possible, that the granite blocks were originally deposited upon a more level soil, and have been raised up with the calcareous mountains, at a subsequent period?*

If the mountains and valleys were already raised and excavated, when these blocks were transported, they could have been carried over the Jura only by a mighty deluge, which had covered the summits of the Alps, and submerged all the present continents under its waves. Nor are there wanting proofs of such extensive inundations, in every country of the old world, that has yet been examined.

To return to the causes which are in the present time wearing down the surface of islands and continents.—The action of the sea upon the cliffs in England, proves in a striking manner the changes which this important agent can effect in the space of a few centuries, and sometimes in a few years. In Devonshire and Dorsetshire, on the coasts of Sussex, Kent and Suffolk, the sea has made great incroachments on the land since the time of the Norman conquest; as may be proved both by ancient records, and by what is now taking place, the cliffs being undermined by high tides, large portions of land are yearly falling into the sea.

It may however be doubted, whether the surface of dry land is not gradually increasing on the whole globe. The depositions from the sea and from rivers are filling up bays, estuaries and lakes: all broad flat valleys, and almost all low and fertile plains, were once covered with water. On the eastern part of our own island, though the land is wearing away in some parts, it is increasing more rapidly in others. The flat parts of Lincolnshire, Cambridgeshire, and Holderness in Yorkshire, have been gained from the sea, or from rivers, by depositions of sand and mud at no very remote period; and the process is going on daily. In many parts, the sea during high tides is above the present level of the land, and is kept out by embankments. In Yorkshire, the proprietors contrive to raise the surface of the ground, by what is called *warping*. At the highest spring tides, they open sluices in the embankments, and cover the land with the turbid sea-water, which remains until it has deposited its contents, and is let out at low water. The quantity of earthy matter held in suspension by rivers after heavy rains is prodigiously great. According to Major Rennell, a glass of water taken from the Ganges at the height of its inundations, yields one-fourth sediment. Mr. Barrow says, in his account of China, that the quantity of mud brought down by the Yellow River, was found by calculation, founded on experiment, to exceed two million solid feet per hour; and that some miles distant from the sea the river was three quarters of a mile broad, and was running at the rate of seven or eight miles an hour. A great part of the enormous mass of mud, which is perpetually brought down by the Yellow River, is borne by strong currents from the Yellow Sea into the Gulph of Petchelee, where the stillness of the water allows it to subside. Into the same gulph, the river of Peking discharges itself; and Mr. Barrow observes, that a great part of the land adjoining this gulph, has apparently been formed by the sand and mud brought into it; for the tide flows inland one hundred and ten miles, and often inundates the whole country, the general level of which is not more than two feet above the level of the river; indeed, the deepest part of the great gulph of Petchelee, does not exceed twelve fathoms, and the prodigious number of sandy islands just appearing above the surface, are said to have been formed within the records of history. (*Barrow's China*, p. 492.)—From the above account, there is every probability, that this wide gulph will soon be filled up by alluvial and marine depositions. The Gulph of Mexico, according to Humboldt, is gradually filling by the sand brought into it from the Caribbean Sea on the south side, and from the west rivers, the Rio del Norte and the Mississippi. The increase of land at the mouth of the Nile, and of many European rivers, is well known. Adria, which was once a port of the Adriatic Sea, (to which it gave its name,) is now six leagues in-land. In lakes, the diminution of the surface, by the gradual increase of land at the mouths of the rivers which flow into them, is still more remarkable. The mud and debris brought into the lake of Geneva by the Rhone, and deposited near its entrance, has made the land advance two miles in the space of seventeen hundred years,—the Roman harbour Portus Valesiæ being now that distance from the lake. All the lakes in Savoy and Switzerland, and in our own island, are gradually diminishing by similar causes. To multiply instances of this kind, would be incompatible with the limits of the present volume; every attentive observer must have noticed them in the course of his travels.

All the most fertile parts of the globe were formed by alluvial depositions: alluvial agency appears to have been the means employed in the œconomy of nature, to prepare the world for the residence of social and civilized man: the most ancient cities of which we have any authentic record, Babylon, Ninevah, and Thebes, were founded in the midst of alluvial soils, deposited by the Euphrates, the Tigris and the Nile: indeed it does not appear unreasonable to believe, that the formation of soils for the support of vegetables and animals, was the final cause for which the world was created and to which all terrestrial changes ultimately refer.

It has been justly observed by Dr. Paley and others, that in the peculiar conformation of the teeth in graminivorous animals, and in the production of grasses which serve them for food, we may trace evident marks of relation, and of a designing intelligent cause. With equal reason must we admit, that the destruction of mountains and the formation of soils for the support of the vegetable tribes are provided for by the same cause, and are part of a regular series of operations in the œconomy of nature. Hence also we may infer, that those grand revolutions of the globe, by which new mountains or continents are elevated from the deep, are part of the same series, extending through ages of indefinite duration, and connecting in one chain, all the successive phenomena of the material universe.

By a wise provision of the Author of nature it is ordained, that those rocks which decompose rapidly, are those which form the most fertile soils; for the quality of soils depends on the nature of the rocks from which they were formed. Granitic and siliceous rocks form barren and sandy soils; argillaceous rocks form stiff clay; and calcareous rocks, when mixt with clays, form marle; but when not covered by other strata, they support a short, but nutritous vegetation. For the formation of productive soils, an intermixture of the three earths, clay, sand, and lime, is absolutely necessary. The oxide of iron appears also to be a requisite ingredient. The proportion necessary for the formation of good soil, depends much on the nature of the climate, but more on the quality of the sub-soil, and its power of retaining or absorbing moisture. This alone may make a soil barren, which upon a different sub-soil would be exceedingly productive. When this is the case, drainage or irrigation offers the only means of permanent improvement.

Different vegetables also require different admixtures of earth. They require it, first, because it is necessary to their growth, that the soil should be sufficiently stiff and deep to keep them firm in their place; and also that it should not be too stiff to permit the expansion and growth of their roots; and, lastly, that it should supply them with a constant quantity of water, neither too abundant nor deficient. Hence we may learn why different degrees of tenacity, depth and power of retaining or absorbing moisture, are required in soils for different kinds of plants. Thus, in uncultivated countries, we find that certain vegetables affect particular situations in which they flourish spontaneously and exclusively; and it is only by imitating nature, and profiting by the instruction she affords, that we can hope to obtain advantageous results, or acquire certain fixed principles to guide us in our attempts, to bring barren lands into a state of profitable cultivation. When rocks contain in their composition a due proportion of silex, clay, and lime, they furnish soils whose fertility may be said to be permanent. The most fertile districts in England were made so by nature; their original fertility was independent of human operation.

Some small portion of the earths and alkalies is found by chemical analysis in plants: but it would be contrary to fact and analogy to suppose, that the earths in a concrete state, form any part of the food of plants: the earths and alkalies which they contain, are in all probability formed by the process of vegetation from more simple elements; for it is now ascertained, that the earths and alkalies are compound substances.

The principal elements found in plants are hydrogen, carbon, and oxygen; and by experiments of Gay Lussac and Thenard,* it appears that the hydrogen and oxygen in starch, gum, vegetable oils, and sugar, exist in precisely the same proportions that form water. Carbon, the other principal elementary substance found in plants, exists both in water and in the atmosphere. Water and the atmosphere contain in themselves, or in solution, all the elements necessary for the support and growth of vegetables. But most soils are either too wet or too adhesive, to admit plants to extract these elements, in the proportions necessary for their growth. Manures supply this deficiency by furnishing in great abundance the hydrogen, carbon, or azote, which they may require. In proportion as soils possess a due degree of tenacity, and power of retaining or absorbing heat and moisture, the necessity for a supply of manure is diminished; and in some instances the earths are so fortunately combined, as to render all supply of artificial manure unnecessary. He who possesses on his estate the three earths,—clay, sand, and lime,—of a good quality, with facilities for drainage or irrigation, has all the materials for permanent improvement; the grand desiderata in agriculture being to render wet lands dry, to supply dry lands with sufficient moisture, to make adhesive soils loose, and loose soils sufficiently adhesive.

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* Recherches Physico-Chimiques.

The intermixture of soils, where one kind of earth is either redundant or deficient, is practised in some countries with great advantage. Part of Lancashire is situated on the red sand rock described in the sixth chapter. This rock, being composed principally of siliceous earth, and the oxide of iron, forms of itself very unproductive land: but fortunately, in many situations it contains detached beds of calcareous marle near the surface. By an intermixture of this marle with the soil, it is converted into fertile land, and the necessity for manure is superseded. The effect of a good marle applied liberally to this land, lasts for more than twenty years. In some lands, a mixture of light marle which contains scarcely a trace of calcareous earth, is found of great service. The good effect of this appears to depend on its giving to the sandy soil a sufficient degree of tenacity. The sterile and gravelly soils in Wiltshire, have been recently rendered productive, by mixing them with chalk; the most liberal application of manure having been found ineffective or injurious. In stiff clay soils, where lime is at a great distance, the land might frequently be improved by an intermixture with siliceous sand. A proper knowledge of the quality of the sub-soil, and the position of the sub-strata, is necessary to ascertain the capability of improvement which land may possess. It may frequently happen, that a valuable stratum of marle or stone, which lies at a great depth in one situation, may rise near the surface in an adjoining part of the estate, and might be procured with little expense.

Lime is the only earth which has been generally used to intermix with soils, and has been considered as a manure; but its operation as such is very imperfectly understood. Burnt lime, when caustic, destroys undecomposed vegetable matter, and reduces it to mould,—so far its use is intelligible. It combines also with vegetable or mineral acids in the soil, which might be injurious to vegetation,—here its operation is likewise intelligible: but if we assert that when burnt lime has absorbed carbonic acid and become mild, it gives out its carbon again to the roots of plants, we assume a fact, which we have neither experiments nor analogies to support. The utility of lime in decomposing vegetable matter and neutralizing acids is obvious: but its other uses are not so evident; except we admit that it acts mechanically on the soil, and renders the clay or sand with which it is intermixed, better suited to the proper expansion of the roots, and more disposed to modify the power of retaining or absorbing the requisite degree of heat and moisture, which particular vegetables may demand.

Where earths are properly intermixed, instances are known of land producing a succession of good crops for many years without fallowing or manure. On the summit of Breedon Hill, in Leicestershire, I have seen a luxuriant crop of barley growing on land that had borne a succession of twenty preceding crops, without manuring. This is more deserving notice, being in an exposed and elevated situation, and upon the very hill of magnesian lime, which has been so frequently referred to by chemical writers, as peculiarly unfavourable to vegetation. The limestone of this hill contains about 20 per cent of magnesia.*

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* The magnesian lime acts more powerfully in destroying undecomposed vegetable matter than common lime, and its effects on land are more durable: hence it is in reality of greater value in agriculture, as a much smaller quantity will answer the same purpose.

The temperature requisite for the growth of plants is influenced by the power of different soils to absorb and retain heat from the solar rays, which depends much on their moisture and tenacity. " It is a well known fact, that the vegetation of perennial grasses in the spring, is at least a fortnight sooner on limestone and sandy soils, if not extremely barren, than on clayey or even in deep rich soils; it is equally true, but perhaps not so well known, that the difference is more than reversed in the autumn."—(Observations on Mildew, by J. Egremont, Esq.)—This effect Mr. E. ascribes with much probability to the rich or clayey soils absorbing heat slowly, and parting with it again more reluctantly than the calcareous soils, owing to the greater quantity of moisture in the clay, which is an imperfect conductor of heat.

Calcareous soils might frequently be much improved by a mixture of clay, sand, or gravel, which in many situations is practicable with little expense, and would well reward the labour of the experimental agriculturist.

Calcareous Tufa.—Beside the new land formed by alluvial depositions, beds of calcareous tufa are sometimes formed in valleys, and at the bottom of lakes, by a process which bears some analogy to chemical formations. Springs containing carbonic acid, that issue from limestone strata, contain particles of carbonate of lime chemically disolved in the water; but on exposure to air and light, the carbonic acid, which had but a slight affinity for the particles of limestone, separates, and the particles of lime are precipitated and form calcareous incrustations: these in course of years form thick beds, and are sometimes sufficiently hard to be used for building-stone. The Rock Mill, near Stroud in Gloucestershire, is built of this stone. In almost all limestone countries, there are instances of calcareous incrustations formed in springs, which have received the name of petrifying wells.

In the first edition of this work, I ventured to predict that were ancient lakes laid dry, we should have instances of freshwater formations; and this prediction has been verified. See an interesting paper on the recent freshwater limestone in Forfar-shire, by Charles Lyell, Esq. (Geological Transactions 1826,) of which I shall give a brief notice, after inserting what I had stated respecting the lakes of America.

On the continent of America, nature acts upon a magnificent scale. Were her operations attended to, they might illustrate many interesting facts in geology.

The lakes of North America are seas of fresh water more than fifteen hundred miles in circuit: these are placed at a considerable elevation above the Atlantic, and at different levels. They unite by small straits or rivers, which have a rapid descent. On some of them are prodigious waterfalls, which are constantly enlarging and shortening the passage from one to the other, and will ultimately effect the drainage of the upper lakes. The falls of Niagara are well known. The water is divided by a small island, which separates the river into two cataracts, one of which is six hundred and the other three hundred and fifty yards wide, and from one hundred and forty to one hunded and sixty feet in depth. It is estimated, that six hundred and seventy thousand tons of water are dashed every minute with inconceivable force against the bottom, undermining and wearing down the adjacent rocks. Since the banks of the cataract were inhabited by Europeans, they have observed that it is progressively shortening the distance from lake Erie to lake Ontario. When it has worn down the intervening calcareous rocks and effected a junction, the upper lake will become dry land, and form an extensive plain, surrounded by rising ground, and watered by a river or smaller lake, which will occupy the lowest part. In this plain, future geologists may trace successive strata of freshwater formation, covering the subjacent crystalline limestone. The gradual deposition of minute earthy particles, or the more rapid subsidence of mud from sudden inundations, will form different distinct beds, in which will be found remains of freshwater fish, of vegetables, and of quadrupeds. Large animals are frequently borne along by the rapidity of the current, and precipitated down the cataracts; their broken bones mixed with calcareous sediment, may form rocks of calcareous tufa, where the waters first subside after their descent.

The small lake described by Mr. Lyell, is about nine miles west of Forfar. It once extended over two hundred acres, but is now reduced to a peat moss, or swampy hollow in diluvium. The bed of the lake has been in a great part excavated for marle, it contains different strata, of variable thickness. The upper covering is peat, one or two feet thick, under which is shell or rock marle varying from one to sixteen feet. Quicksand two feet, and lower shell marle of a good quality, from one to two feet thick, resting on a bed of fine sand, of variable thickness. The rock marle consists wholly of carbonate of lime, it is hard and compact, and in some parts crystalline. The lower shell marle rarely contains any distinguishable quantity of shelly matter. In the rock marle are found shells of Helices, the Turbo fontinalis, and the Patella lacustris.

There are remains of land quadrupeds in the shell marle, but not in the rock marle. The rock marle, (it appears from Mr. Lyell's description,) nearly resembles the upper freshwater limestone in the Paris basin, and like it, is traversed by tubular cavities. Some part of the rock marle is however stated to be a tufaceous limestone. This recent formation of freshwater limestone, is in so many respects analogous to the most recent formation of freshwater strata of the ancient world, that all the particular circumstances described by Mr. Lyell, deserve the careful attention of the geologist.

Peat is a substance which has been classed with alluvial soils, though it is obviously a vegetable production. Peat formerly covered extensive tracts in England, but is disappearing before the genius of agricultural improvement, which has no where produced more important effects, than in the conversion of the black and barren peat moors of the northern counties, into valuable land covered with luxuriant herbage, and depastured by numerous flocks. The following description of the peat moors in Scotland, by Mr. Jameson, is an accurate picture of the remaining peat moors in the mountainous parts of Yorkshire, and the adjoining counties.

"In describing the general appearance of a peat moor, we may conceive an almost entire flat of several miles extent, of a brown colour, here and there marked with tufts of heather, which have taken root, owing to the more complete decomposition of the surface peat; no tree or shrub is to be seen; not a spot of grass to relieve the eye, in wandering over this dreary scene. A nearer examination discovers a wet spongy surface, passable only in the driest seasons, or when all nature is locked in frost. The surface is frequently covered with a slimy black-coloured substance, which is the peat earth so mixed with water, as to render the moss passable only by leaping from one tuft of heather to another. Sometimes, however, the surface of peat mosses has a different aspect, owing to the greater abundance of heath and other vegetables as the schœni, scirpi, eriophora, &c.: but this is principally the case with some kinds of what are called muirlands, which contain but little peat, being nearly composed of the interwoven roots of living vegetables. Quick moss (as it is called) is a substance of a more or less brown colour, forms a kneadable compound, and when good, cuts freely and clean with the spade; but when it resists the spade by a degree of elasticity, it is found to be less compact when dried, and is of an inferior quality. The best kinds burn with a clear bright flame, leaving light-coloured ashes; but the more indifferent kinds in burning often omit a disagreeable smell, and leave a heavy red coloured kind of ashes. In digging the peat we observe that when first taken from the pit it almost immediately changes its colour, which becomes more or less a deep brown or black, and the peat matter becomes much altered, being incapable of forming a kneadable paste with water. When dry and reduced to powder, as it is often by the action of the weather, it forms a blackish-coloured powdery matter, capable of supporting vegetation, when calcareous earth is added.

" Peat is found in various situations, often in valleys or plains, where it forms very extensive deep beds, from three to forty feet deep, as those in Aberdeenshire: it also occurs upon the sides of mountains; but even there, it is generally in a horizontal situation. The tops of mountains, upwards of two thousand feet high, in the Highlands of Scotland, are covered with peat of an excellent kind.

"It is also found in situations nearly upon a level with the sea: thus, the great moss of Cree in Galloway, lies close upon the sea, on a bed of clay, little higher than the flood marks at spring tides."*

In the first volume of Dr. MacCulloch's valuable History of the Western Islands of Scotlands, he has given a luminous description of the formation of peat, which completes the natural history of peat moss. Beside the Sphagnum palustre, he has enumerated nearly forty plants which concur to the generation of peat.

"The process by which these vegetables are converted into peat, is most clearly seen in the sphagnum. As the lower extremity of the plant dies, the upper sends forth fresh roots like most of the mosses, the individual thus becoming in a manner immortal, and supplying a perpetual fund of decomposing vegetable matter. A similar process, though less distinct, takes place in many of the rushes and grasses, the ancient roots dying together with the outer leaves, while an annual renovation of both, perpetuates the existence of the plant. The growth of peat, necessarily keeps pace with that of the vegetables from which it is formed; hence the necessity of replacing the living turf on the bog where peat has been cut,—a condition now required in all leases, in which liberty to cut turf is included. On the conversion of vegetable matter into peat, Dr. MacCulloch observes: "Where the living plant is still in contact with peat, the roots of the rushes, and ligneous vegetables, are found vacillating between life and death, in a spongy half-decomposed mass. Lower down, the pulverized carbonaceous matter is seen mixed with similar fibres, still resisting decomposition. These gradually disappear, and at length, a finely powdered substance alone is found, the process being completed by the total destruction of all the organized bodies." p. 130. The best peat is that of which the decomposition is most complete, and the specific gravity and compactness the greatest. The quality of peat, Dr. MacCulloch observes, is much affected by the wetness or dryness of the soil, and the elevation or other causes, which influence the temperature or moisture of the atmosphere.

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* Jameson's Mineralogy of the Shetland Islands.

For a description of the chemical changes produced in peat by water and fire, I must refer to the 1st volume of Dr. MacCulloch's work before quoted. p. 131. It is only in the first stages of decomposition that peat is soluble, and communicates a dark colour to water.

The rapid formation of peat in many situations, where it is found covering ground that was formerly pastured, admits of an easy explanation, since Dr. MacCulloch has so clearly described the mode, in which this substance is generated.

The property possessed by peat of preserving animal matter from putrefaction, is well deserving notice. It is probably owing to this, that some of the fleshy parts of the mastodon, have been so long preserved in peat bogs.

In the *Philosophical Transactions* 1734, there is a letter from Dr. Balguy, giving an account of the preservation of two human bodies in peat for fifty-nine years. "On January 14, 1675, a farmer and his maid-servant were crossing the peat moors above Hope, near Castleton in Derbyshire; they were overtaken by a great fall of snow, and both perished: their bodies were not found till the 3d of May in the same year: and being then offensive, the coroner ordered them to be buried on the spot in the peat. They lay undisturbed twenty-eight years and nine months, when the curiosity of some countrymen induced them to open their graves. The bodies appeared quite fresh, the skin was fair and of its natural colour, and the flesh as soft as that of persons newly dead. They were afterwards frequently exposed as curiosities, until in the year 1716, they were buried by order of the man's descendants. At that time, Dr. Bourne of Chesterfield, who examined the bodies, says the man was perfect, his beard was strong, the hair of his head was short, and his skin hard and of a tanned leather colour, like the liquor he was lying in. The body of the woman was more injured, having been more frequently exposed; the hair was like that of a living person. Mr. Wornald, the minister of Hope, was present when they were removed: the man's legs, which had never before been uncovered, were quite fair when the stockings were drawn off, and the joints played freely without the least stiffness."

In the beginning of the last century, the perfect body of a man in the ancient Saxon costume, was discovered in peat, at Hatfield Chase in Yorkshire: it soon perished on exposure to the air.

Extensive tracts of cultivated ground are sometimes converted into sandy deserts, by the drifting of sea-sand inland. The process by which this is effected, is taking place, at present, in many situations. During very high winds, the sand is driven from the sea shore to a certain distance, leaving an elevated ridge at the further boundary of the drift. Succeeding winds blow the sand forward, and at the same time bring fresh sand from the shore to supply its place. In the sixth volume of the *Transactions of the Irish Academy*, an account is given of the encroachment of the sand, over some parts of Ireland. Trees, houses, and even villages, have been surrounded or covered with sand, during the last century. In the vicinity of sandy deserts, the sand is also encroaching on the habitable land. The loose sands of Libya are thus spreading over the valley that borders the Nile, and burying the monuments of art, and the vestiges of former cultivation. From a similar cause, the country immediately round Palmyra, that once supplied a crowded population with food, now scarcely affords a few withered plants, to the camel of the wandering Arab.

A sandy inundation on the north coast of Cornwall was mentioned Chapter I. page 24. This sand, which is composed of fragments of shells and coral, is in some parts cemented into sandstone by water infiltrating from the slate-rocks: it is similar in appearance to the recent sandstone of Guadaloupe, in which human skeletons have been found: the latter is a very common sandstone in the West Indies; it increases rapidly, and the land gained from the sea, which forms some of the plains of St. Domingo, is composed of it. A concreted calcareous sandstone extends on the southern, western, and north-western coast of Australasia, for three thousand miles. Some specimens which I examined with a lens, appear perfectly similar to the recent sandstone from Guadaloupe.

Among the causes in present activity, which are changing the surface of the globe, the labours of madrepores must not be unnoticed. These minute polypi, raise up walls and reefs of coral-rock with astonishing rapidity in tropical climates, and encircle the present islands with belts of coral, thus enlarging their coasts. A coral reef of seven hundred miles in length, extends from the north-west of Australasia towards New Guinea. For a detailed account of coral rocks and reefs, I must refer the reader to the Observations of Dr. Forster, and the voyages of Captain Flinders and of Kotzebue. The French naturalists MM. Quoi and Gaimard have, however, recently shown, that madrepores which form coral-rocks, do not commence their operations at greater depths than twenty-five or thirty feet below the surface of the sea: they construct their habitations on the summits of submarine rocks, and increase their height, but do not form them. The quantity of calcareous matter which these madrepores furnish, cannot (they say) be compared with the quantity of materials which testaceous animals have furnished, and still continue to furnish, to the crust of the globe.

Organic remains in diluvial beds and caverns.—The fossil elephant, or mammoth, is the most remarkable of the ancient herbivorous quadrupeds, both from its vast size, and the amazing number of bones of this genus, which are found in the northern parts of Europe, and in America. It must have existed in herds of hundreds and thousands. According to Pallas, there is scarcely a river, from the Don, or the Tanais, to the extremity of the promontory Tchuskoinosa, in the banks of which, the bones of the mammoth are not abundant. There are two large islands near the mouth of the river Indigerska, which are said to be entirely composed of the bones of the mammoth, intermixed with ice and sand; the tusks are so perfect, that they are dug out for ivory. With the bones of the mammoth, are intermixed those of the elk, the rhinoceros, and other large quadrupeds.

The body of a fossil elephant has been found entire, with the flesh preserved, buried in ice: it had a mane along its back, and was covered with coarse red wool, protected by hair of a coarser kind, indicating that it was an inhabitant of cool climates; indeed, the circumstance of the body being preserved in ice, is a further proof of this; for had it been conveyed from distant regions, or had the temperature of northern latitudes been much higher at that period, than at present, the flesh must have been speedily decomposed, before it could have been enveloped in ice. The height of this animal was from fifteen to eighteen feet. Bones and teeth of the mammoth are not unfrequently found in England, in beds of diluvial gravel and clay, and in caverns: they are found chiefly in low situations, such as the Vale of the Thames, and the Vale of the Severn. The mammoth bears a near resemblance to the Indian elephant, but Cuvier regards it as a distinct species.

The rhinoceros, of which there are three large species, and one smaller, appears to have lived with the fossil elephant: their bones are found together; but it is in Siberia, that the bones of the rhinoceros are most numerous, and best preserved. In the year 1771, the entire body of one of these animals, was found in the frozen sands of that country.

Bones and teeth of the hippopotamus are found in England, France, Germany, and Italy: there are two species; the largest resembles the African hippopotamus, the smaller is the size of the wild boar. Bones and teeth of a large animal, called the mastodon, are found both in Europe and America. The great mastodon had pointed grinders; it was a native of North America, and equalled in size the elephant, which in many particulars it resembled. Its bones, and even entire skeletons, have been found in salt-marshes: but what is more extraordinary, parts of the flesh and the stomach, have been found with them. Among the vegetable substances in the stomach, were distinguished the remains of some plants known in Virginia. The Indians believe, that this animal is still living north of the Missouri; and the above circumstances render it probable, that this species of mastodon has not been long extinct. Bones of other species of the mastodon are found in Europe and South America; these are probably more ancient. Teeth of a gigantic species of tapir, equal in size to the rhinoceros, have been found in France and Germany:* the bones of horses are also found in great abundance, with the bones of the above-mentioned animals. Bones and horns of the elk, the stag, and of various species of deer, and of oxen, some of which closely resemble existing species, are often intermixed with the bones of elephants and other ancient animals. With these animal remains, are also found the bones of carnivorous animals of the size of the lion, the tiger, and the hyena; the bones of bears are numerous, particularly in caverns.

The number of bones belonging both to the order of pachydermata, and of ruminant and carnivorous quadrupeds, is so great in various parts of Europe, as to leave no doubt that the animals were inhabitants of northern or temperate climates. In America have been found the bones of two large animals, of extraordinary form. The megatherium is the size of the rhinoceros; it unites part of the structure of the armadillo, with that of the sloth; its claws are of vast length and size. The megalonix was nearly similar in form, but smaller.

Bones of the camel, and some other species of large mammiferous quadrupeds have been occasionally found, but they are of rare occurrence. For a knowledge of nearly all the above species of fossil mammiferous quadrupeds, we are indebted to the researches of Cuvier. Their bones, he observes, "are found in that mass of earth, sand and mud, that diluvium, which covers our large plains, fills our caverns, and chokes up the fissures in many of our rocks. They incontestibly formed the population of the continents, at the epoch of the great catastrophe, which has destroyed their races, and has prepared the soil, on which the animals of the present day subsist. Whatever resemblance certain of these species bear to those of existing species, the general mass of this population had a different character; the greater part of the races which composed it, have been utterly destroyed. Among all these mammiferous animals, the greater number of which have their congeners living at the present day, there has not been found a single bone or tooth of any species of ape or monkey. Nor is there any trace of man: all the human bones which have been found along with those of which we have been speaking, have occurred accidentally; and their number besides is exceedingly small, which assuredly would not have been the case, if men had been then settled in the countries which these animals inabited." When Cuvier published the first edition of his *Recherches sur les Ossemens fossiles*, he too hastily concluded, that we were already acquainted with all the existing species of large land quadrupeds; and hence he inferred, that it was highly improbable, that any of the species of unknown quadrupeds, whose bones are found in diluvial soils, should be still living. Since that time, a large species of living tapir has been found in the East Indies; and other discoveries of new quadrupeds have been made: hence we cannot conclude with absolute certainty, that all the species of unknown fossil quadrupeds are extinct, though it seems highly probable that the greater number of the races have perished. The animals whose bones are found in peat bogs and marshes,—such as the elk in Ireland, and the great mastodon in Kentucky,—may, I conceive, be referred with much probability, to a more recent epoch, than that in which the diluvial beds were deposited.

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* The most perfect tooth of this animal which is at present known, was found near Grenoble; the enamel is as fresh as that of a recent tooth. This tooth, of which their are models in the principal museums in Europe, is in the author's collection; it was purchased by him, at the sale of the late M. Faujas St. Fond, together with the tooth of a South American mastodon found in the volcano of Imbabura in the Cordilleras, and the tooth of a European mastodon, found with that of the gigantic tapir, near Grenoble.

Skeletons, both of the Irish elk and the great American mastodon, have been found erect in peat bogs and marshes, which proves that the surface of the ground has undergone little change since the animals perished; and the further circumstance, of the flesh and stomach of the mastodon being found near the surface, not protected, like the bodies of the elephant and rhinoceros found in Siberia, by ice, seems to preclude the belief in the high antiquity of these animal remains; and it is admitted by Cuvier, that they are in better preservation than any other fossil bones. The quadrupeds whose bones are buried in beds of clay, sand or gravel, or accumulated in caverns, undoubtedly lived in a very remote period, and under a different condition of our planet to the present one. The northern parts of Europe seem now incapable of supporting the immense number of elephants, which have formerly spread over all the valleys bordering the Frozen Ocean. Were we to suppose that the temperature of the earth was then higher than at present, which the remains of palms and other tropical plants found in northern latitudes would render probable, this would not remove the difficulty; for the fact, that entire bodies of elephants have been preserved in ice, and that their skins were covered with a thick coat of wool and hair, proves that these animals were constituted for living in cold climates, and that their remains have not been transported to any great distance, from the countries which they inhabited.*

The remains of these large quadrupeds occur in different states of preservation. In the frozen regions of the North, the ivory of the tusks is perfect. In beds of clay, the bones and teeth are frequently impregnated with mineral matter; but in gravel they are generally in a loose or friable state, or at least they soon become so after exposure to the air. In the *Phil. Journal of Edinburgh*, January 1828, an account is given of numerous bones of the mastodon, rhinoceros and other animals, having been found on the surface of the ground, near Irrawady River, in Ava. These bones, though exposed to the atmosphere, are stated to be extremely hard, being impregnated with iron; but of the causes by which this impregnation was effected, we are at present ignorant.

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* A friend has suggested, that the Siberian elephants were probably migratory, and passed the winter months in more temperate latitudes. If this were the case, individuals that from lameness or disease were unable to travel, may have been incrusted with ice immediately after death.

The bones of carnivorous animals are most abundant in caverns: there are some circumstances which render their occurrence in such situations very difficult to explain in a satisfactory manner.

It has been long known to naturalists and travellers, that there are numerous caverns in the calcareous mountains of Germany and Hungary, the floors of which are covered with clay, enveloping a prodigious quantity of bones and teeth of carnivorous animals. The bones in these caverns are nearly the same, over an extent of more than one hundred leagues. More than three fourths belong to species of bears that are now extinct;[*] two thirds of the remaining part belong to an unknown species of hyena; a smaller number belong to a species of lion or tiger, or of the wolf or dog; a very few belong to small carnivorous animals, allied to the fox and polecat. The bones are nearly in the same state in all these caverns: they are found scattered and detached, partly broken, but never rounded by attrition, and consequently not brought from a distance by water. They are rather lighter and more fragile than recent bones, but still preserve their true animal matter, containing much gelatine, and are not in the least petrified. The bones are all enveloped in earth which is penetrated with animal matter; except a few bones on the surface, of a different kind, which have been brought there at a later period, and are less decomposed.

The most remarkable of these caverns are those of Gaylenreuth on the left bank of the river Wiesent, in Bavaria; they vary in height from ten to forty feet, and are connected by narrow low passages. The animal earth intermingled with bones, is in many places more than ten feet deep; according to the account of a German writer, M. Esper, would fill many hundred waggons. There is also a cavern, or series of caverns, at Adelsberg in Carniola, much larger than any in Germany: the caves are of variable dimensions, and are stated to extend more than three leagues in a right line, at which distance there is a lake which prevents further access. The floors of these caverns are covered with indurated clay, enveloping the bones of bears, and other carnivorous animals, similar to those in the caverns of Germany and Hungary. In one part of this cavern, or series of caverns, the entire skeleton of a young bear was discovered, enveloped in clay or mud, between blocks of limestone which lay on one side of the cave. Adelsberg is situated on the great road from Trieste to Laybach, and has been much visited by travellers. The river Pinka is lost in this cavern, terminating in a subterranean lake, from which another river emerges on the northern side, which has received the name of Unz. There are incrustations of stalactites in these, as well as in all other calcareous caverns; and in many parts, the bones and earthy matter are covered by stalactites. Formerly, these bones formed an important article of commerce, being used in medicince, and sold under the name of the fossil unicorn. Single skeletons of large quadrupeds have formerly been discovered in caverns in this country; but we had no authentic account of the bones of carnivorous animals having been found in any English caves, previously to the year 1821; when some labourers working in a quarry at Kirkdale near Kirby Moorside, in Yorkshire, discovered an opening covered over with rubbish and earth, about 100 feet above the neighbouring brook. This was the mouth of a low cavern, extending about 200 feet into the rock. The floor of the cavern was covered with broken bones and teeth of various animals, encased in a stratum of mud about a foot thick. Fortunately, this cavern was examined by Professor Buckland of Oxford, soon after its discovery; who has published a very luminous account of its structure and contents, elucidated by references to the most remarkable caverns in other countries which he has visited, containing bones of carnivorous animals. The bones in the Kirkdale Cave are broken and gnawed, and some of them preserve the marks of the teeth which have fractured them. Even the excrements of animals similar to those of the hyena, have been discovered with them. The bones in this cave differ much from those in the caves of Germany; as a great number of them belong to herbivorous animals, and the carnivorous animals whose remains are most abundant, are hyenas. Among these remains, Professor Buckland has ascertained bones of the following orders:—

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[*] The most common species of bear in these caverns, the Ursus Spelæus, was of the size of a horse. The fossil hyena was one third larger than any known living species

Carnivorous Quadrupeds.—The hyena, tiger, bear, wolf, fox and weasel.

Pachydermata.—The elephant, rhinoceros, hippopotamus, and horse.

Rodentia or *Gnawers.*—The hare, rabbit, rat, water-rat, and mouse.

Ruminant Animals.—The ox, and fragments and bones of three species of deer.

Birds.—The raven, pigeon, lark, snipe, and a small species of duck.

From the great number of the bones of the hyena found in this cave, Professor Buckland infers that it had long been the habitation of these animals. It is their ascertained habit partly to devour the bones of their prey; they also devour the dead bodies of their own species; like wolves they are gregarious and hunt in packs. From the habits of the hyena, he explains the occurrence of the remains of large herbivorous quadrupeds like the elephant in so low a cave as that of Kirkdale; they have been dragged into it by these voracious animals. Several English caverns have since been explored. In some of them there are bones both of herbivorous and carnivorous animals, similar to those in the Kirkdale Cave. These caves are described in Professor Buckland's valuable work entitled *Reliquiæ Diluvianæ.*

That the caverns in which the bones of carnivorous animals are found in such prodigious quantities, were the retreats of some of these animals, cannot be doubted. Many circumstances described in the account of the Kirkdale Cave, can be explained only by admitting it. There are, however, other circumstances, particularly in the caves of Germany, which would imply, that part of the bones belong to animals that had fallen through fissures, which formerly opened into these caverns, or that the bones themselves had been carried by water through these fissures. In the cave at Galenreuth, there are rounded fragments of limestone, intermixed with the bones, and the entrance of some of the caverns *is much too small* to have admitted the animals whose bones are found in them. I think it is also probable, that a violent convulsion of nature, as a rising deluge and the fierce war of elements without, might have driven, under the strong impulse of alarm, numerous animals of different species into the same caverns, where they devoured each other, and their bones have been intermixed with those of the former inhabitants. It is also highly probable, that the entrances of many of the caverns, and the caverns themselves, have been formerly more lofty than at present, but have been gradually lowered by the subsidence of the upper strata. Indeed it is admitted, that the caverns and grottoes in the neighbourhood of Adelsberg, have occasioned numerous depressions of the surface. Such an effect must generally take place, in a greater or less degree, with the strata over caverns. Most calcareous caverns appear to have been originally formed by subterranean streams of water, washing out their regular beds of clay between the limestone strata; and when the cavern is formed, the upper strata must gradually or suddenly descend. If the same process of excavation by subterranean water take place slowly, the subsidence may be so gradual, as scarcely to be perceived in the lapse of centuries. I am acquainted with an instance of the gradual subsidence of a hill of oolite in Lincolnshire within the memory of man, supported by undoubted testimony. There is also a fact respecting the calcareous mountains near Ingleton and Settle in Yorkshire, illustrative of the manner in which bones may be introduced into caverns; but still more so, of the manner in which the fissures of calcareous rocks, bordering the Mediterranean Sea, have been filled with bones of herbivorous animals.

The mountain of transition limestone of Craven in Yorkshire, forms in many parts, a nearly flat elevated surface of table land, covered with vegetation, but intersected by numerous fissures or chasms of vast length and depth, varying from a few inches to a foot or more in width. Many of these fissures widen as they descend; and at the bottom, streams of water may be frequently heard running. During snow, it is not uncommon for sheep to be lost in these chasms, and the whole surface is extremely dangerous to traverse in the dark. Limestone plains, intersected by such fissures, may be regarded as natural traps for herbivorous animals, into which they may fall in whole droves, when chased by beasts of prey. Their bones may either stick fast in the fissures, and be afterwards inclosed in calcareous stalactites, or they may be carried by subterranean currents into caverns, which have no communication with the surface. Such was the cavern at the Bull's Eye mine, near Worksworth in Derbyshire, which was opened by mining operations in the year 1663, and contained the entire skeleton of an elephant.

The bones of existing species of animals in peat, or in alluvial soil, may occasionally be found intermixed with fossils from ancient strata; for when the rocks which contain the organic remains of a former world, are exposed to the disintegrating effects of atmospheric action, the fossils being generally harder than the stone in which they are imbedded, fall out, and may be carried down by casual inundations and mixed with recent alluvial deposits. It may also happen that recent bones have been transported by the same cause, and intermixed with ancient diluvial deposits: such intermixtures are not of frequent occurrence, but they should be most carefully noticed by the geologist, or they may be the source of very erroneous inductions.

Baron Cuvier maintains that the anoplotherium, and paleotherium, found in the gypsum strata near Paris, belong to a more ancient creation than the fossil elephant and mastodon. Many facts might be cited (did the limits of the present volume permit,) which oppose the opinion of this distinguished naturalist. The remains of elephahts found in beds analogous to the London clay, and of the mastodon and beaver found under beds of sandstone and limestone at Alpnach, must surely be as ancient, as the quadrupedal remains in the Paris basin.

CHAPTER XIX.

GEOLOGICAL THEORIES.—THE FORMATION OF VALLIES.—DELUGES, AND DENUDATIONS.

There are few subjects on which the opinions of geologists have been more divided, than the formation of vallies. The principal theories that have been advanced, ascribe their formation to one or other of the following causes.

1st, To the original inequalities of the earth's surface.

2d, To excavation by rivers that flow through them.

3d, To the elevation or subsidence of part of the earth's surface.

4th, To excavations caused by the sudden retreat of the sea from our present continent.

5th, To excavations by inundations or deluges, that have suddenly swept over the surface of different parts of the globe.

I shall briefly notice the leading facts that favour or oppose each of these theories.—The phenomena presented by different vallies, are frequently various and complicated, and indicate, that several causes have co-operated in their excavation, or in moulding them into their present form. The disappearance of large portions of strata, from districts which they have once evidently covered, is also a phenomenon of frequent occurrence; and its explanation must be sought, from some of the same causes, that have excavated vallies.

The first of the above theories is that of Werner: he supposed that all the matter of which primary, transition, and secondary rocks are formed, was originally held in solution by water, and that the water, so saturated with mineral matter, covered the whole globe. The primary rocks of granite were formed by chemical precipitation, and their peaked summits and declivities were the result of their original deposition. On the steep sides of these primary mountains were subsequently deposited the different schistose rocks, and all the secondary strata. During the time that these rocks were depositing, the water, though nearly saturated with mineral matter, was capable of supporting animal life, and the shells and remains of zoophytes and fish, were enveloped in the strata at the period of their deposition. According to this theory, when the water retired from the present continents, the mountains and vallies were already formed.

The theory of Werner requires for its support the admission of conditions, which appear in the present state of our experience impossible, and it is at variance with existing phenomena. The vertical position of beds of pudding-stone, sandstone, and the tertiary strata in the Alps, could not have been their original one; nor can the bendings and contortions of the strata, so common in Alpine countries, be explained by original deposition. A further account of part of Werner's theory is given, Chap. IX. page 161.

The second theory, That all vallies have been excavated by the rivers that flow through them, was maintained by Dr. Hutton and Professor Playfair: it formed a part of their general theory of the earth; the leading propositions of which are, that the surface of the present continents is wearing down by the action of the atmosphere and by torrents, and that the materials are carried by rivers into the sea, and there deposited. At a future period these materials will be melted or consolidated by subterranean heat under the pressure of the ocean, and subsequently, by the expansive force of central fire, the bed of the ocean will be elevated, and form new continents. According to this theory, our present continents have been also formed from the ruins of a preceding world, and elevated by a similar cause. It is only with that part of the Huttonian system which relates to the excavation of valleys, that we have at present any concern. It is remarkable, that a theory which maintains that the continents were raised from the ocean by subterranean fire, should limit the formation of vallies to the action of the rivers that run through them; for if the land were raised by an expansive power acting from beneath, it seems to follow as a necessary corollary, that the surface would be unequally elevated, and broken into inequalities by the same cause; unless we suppose, that every part presented an equal degree of resistance to the moving force. There must, therefore, have been original inequalities or vallies, which determined the direction of the water-courses in the first instance, though the form of these vallies may have been subsequently modified, by the action of water. That all vallies have been excavated by the rivers that flow through them, is opposed by many decisive facts. Before their excavation, the water must have had less force than at present, as the fall would be gentle; and the present effect of rivers in large vallies is not to excavate them deeper, but to fill them with alluvial depositions. There are numerous deep valleys in the Alps, that are closed at one end by steep mountains or perpendicular walls of rock, and which were orginally closed, and are now nearly closed, at the other end also. Such are the valley of Thones near Annecy, the valley of Chamouni, and, on a larger scale, they valley of Geneva. It is evident that the valley of Thones, and that of Geneva, have once been filled with water, and formed lakes: by an earthquake, or by the erosion of water, a fissure has been made, which has drained the greater part of these valleys; but it is obvious that the valleys could not have been formed by the original lakes, or by the rivers that flowed into them. If vallies were formed by the erosion of rivers, the lakes through which these rivers flow, must have long since been filled up by the materials brought into them. To say that the lakes were once deeper than at present, is giving up the theory; for lakes are only the deeper parts of vallies.

Had the valley of Borrowdale in Cumberland been excavated by the water that flows from it, the lake of Keswick, at its entrance, must have received all the materials, and been long since choked up. Or had the valley of the Rhone, ten thousand feet deep and sixty miles in length, been excavated by the Rhone, the quantity of matter brought down by this river, would not only have filled the lake of Geneva into which it empties itself, but the broad valley in which the lake lies, must also have been filled up, and raised to the height of the Jura. That the lake of Geneva, and all lakes into which large rivers flow, are gradually filling up, has been before stated; but the valley of the Rhone is not, nor are other valleys becoming deeper. The upper part of this valley has evidently been itself a lake, closed in, or nearly so, by the rocks at Martigny.

The action of torrents in Alpine districts, may have been sufficient to widen fissures already made, or to scoop out glens in the softer beds on the sides of mountains; but they appear inadequate to the original formation of large longitudinal vallies.—Water-courses running on the edges of nearly vertical beds, may scoop out a portion of a softer bed, placed between two hard rocks, and thus form small longitudinal vallies. I have observed several instances of such vallies in the Alps, which may probably have been furrowed by mountain torrents in the course of ages. Some vallies, as Les Echelles, near Chambery, are closed at one end by a perpendicular wall of rock: through this rock a tunnel is made for the road; but it is impossible to conceive, that any action of water-courses could have formed such a valley. There is only a feeble stream that flows from it.* Malm Cove, at the head of the valley of the Aire, in Yorkshire, is a perpendicular wall of limestone two hundred feet high: at its feet the river rises; but no conceivable action of the river could have originally formed this valley. Whatever extension we may reasonably grant to the action of rivers, it will not be found sufficient for the excavation of valleys, except in particular situations.

The third theory, which attributes the formation of vallies to the elevation of mountain ranges, appears to assign a cause, that will explain, in a simple manner, the formation of many vallies; but on examination, it will be found inadequate to explain the phenomena of other vallies, without the concurrence of diluvial action.

If the crust of the globe were broken and raised in parallel ridges, they might form mountain ranges, with vallies between them, like what are observed bordering the central range of the

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*For a particular account of the structure of this valley, see Travels in the Tarantaise, vol. i. page 169.

Alps; the arched stratification of many of the calcareous mountains, and the vertical position of the beds, favour this hypothesis.

In some instances, where the beds of a mountain are raised from an horizontal, to a nearly vertical position, they would leave a chasm proportionate to the part that had been raised; and this might form the bed of a lake. The steep escarpments which the calcareous mountains in Switzerland and Savoy present to the lakes which they border, indicate that the beds of the lakes were formed in the hollows that had been left by the elevation of the mountains. The beds of the mountains on the opposite side, generally slope down to the lakes: hence M. De Luc inferred, that it was these mountains that had sunk down, and left the chasm which forms the bed of the lake. Either of these theories will explain the formation of deep lakes in mountainous countries, in a more satisfactory manner, than that which attributes the deepening of their beds to the erosion of water.

Nor is the elevation of parts of the earth's surface by a power acting from beneath, unsupported by undoubted facts. We have instances in our own island of the strata being broken, and raised five or six hundred feet. (See pages 114 and 145.) And so recently as the year 1822, the bed of the ocean, over an extent of one hundred miles, was permanently raised up, and became dry land. (See page 78.) These facts may make us more ready to acknowledge the operation of a similar elevating power, having acted with greater intensity, and more extensively, in former ages.

Transversal vallies, or those which cut through mountain ranges, nearly at right angles to the direction of the ranges they intersect, may have been originally fissures or openings, made either at the period when the ranges were elevated, or subsequently, by the same causes that have rent and displaced the secondary strata. These fissures may have been afterwards widened by diluvial agency.

Geologists seem now generally agreed, that the action of rivers is not sufficient to explain all the phenomena of vallies, and still less to account for the fragments of rocks scattered over extensive plains, at an immense distance from Alpine districts, where rocks similar to these fragments occur. Another phenomenon of more importance, is altogether inexplicable, by the action of rivers. Immense tracts of the secondary strata, several hundred feet in depth, have, in some districts, been torn off, and the materials entirely removed, except detached patches, which here and there form isolated caps on distant hills; and incontestably prove, that they were once parts of one continuous stratum or formation. Numerous instances of this might be cited in our own island. This local disappearance of a stratum or formation, has properly been called *Denudation*. The theory advanced by Mr. Farey, to explain these denudations, was, that the surface had been broken and swept away by the near approach of a comet. But the most rational explanation that can be offered, is that which ascribes the effect to a mighty deluge, sweeping over the surface of the globe, tearing off part of its crust, and transporting the fragments into distant regions, or into the ocean. The case is one which may be truly said to be *dignus vindice nodus*, and the geologist is compelled to call in the aid of Neptune; for none of the causes in present activity, (however we may imagine them to be increased in power or magnitude,) will be found adequate to produce the denudation of an extensive stratum, and the disappearance of the stony materials, of which it was composed.

It now remains to notice the theories which provide for diluvial agency.

The fourth theory, which attributes the formation of vallies to the sudden retreat of the sea from our present continents, is founded on the admitted fact, that the sea has once covered them; and whether we suppose that the bed of the ocean was deepened in one part by a sudden subsidence, which drew off the water from another part; or that the continents emerged, by an expansive force acting beneath them,—the effect on the water would be nearly the same. This effect, in scooping out valleys, has been compared to what may be observed in miniature "by the drainage of the retiring tides on muddy shores, especially in confined estuaries where the fall is considerable and rapid," the water cutting out channels for its passage as it drains off, but the action of retiring water being necessarily comprised in the fifth theory, that of Deluges, it is unnecessary to dwell longer upon it.

The fifth theory, which ascribes the formation of valleys, and extensive denudations of the strata, to deluges that have suddenly swept over different parts of the globe, has been maintained by Professor Pallas and Sir James Hall. The former conjectured, that the inundations that have covered parts of the Asiatic continent with blocks of stone, beds of gravel, and marine remains, were occasioned by the formation of volcanic islands in the Indian Ocean. Within the period of authentic history, extensive inundations have been occasioned by volcanos and earthquakes, which afford probability to the opinion of Pallas. In the year 1650, a new volcanic island rose from the sea in the Grecian Archipelago; and according to the account of Kircher, a cotemporary writer, it occasioned the sea to rise forty five feet in height, at the distance of eighty miles, and destroyed the galleys of the Grand Signior in the port of Candia. The principal damage done by earthquakes to cities adjoining the sea, is often effected by an enormous wave; the sea, retiring from its bed in the first instance, suddenly returns with a prodigious swell, and in a few moments, rushes over the adjacent country.

Sir James Hall has given greater extension and consistency to this speculation. He supposes, that the upheaving of a large island like Sumatra, might take place so suddenly, as to drive the ocean with great impetuosity over the summits of the highest mountains, and strip off the glaciers, and transport them into distant countries. Ice being specifically lighter than water, the glaciers would carry away the blocks of stone that had fallen upon them from the impending rocks, and had become incased in ice. This theory of Sir James Hall's, would, I conceive, offer a better explanation than any other, for the occurrence of groups of fragments of particular rocks, unmixed with fragments of other rocks. Each glacier, loaded with stones from the rocks above it, may be regarded as a ship freighted with specimens of its native mountains, which it deposits, by thawing, in the place where it ultimately rests. Nor would a wave or swell of the sea, that had covered the highest mountains, suddenly subside; it would sweep repeatedly over the whole surface of the globe, at a lower and lower level each time; breaking down opposing obstacles, opening new passages for the water, and scooping out vallies and cols in the softer beds and strata.* On the whole, the theory of Sir James Hall affords perhaps the most satisfactory explanation of diluvial agency that has yet been advanced. But whatever difficulties may oppose the admission of this or any other theory, the fact that the present continents have been subjected to the action of a deluge, or a mighty rush of waters, which has swept over the highest mountains, seems confirmed by so many coincident phenomena, as scarcely to leave room for doubt.

Granting the agency of a deluge, or a succession of deluges, there are still phenomena left, that their action will not satisfactorily explain. In the midland counties of England, for instance, there are beds of gravel, and fragments of rock, scattered over hills, that are not only far distant from the rocks which have supplied the fragment, but which are separated from them by deep vallies, over which it is supposed that the fragments could not have been carried, by any power of diluvian agency; for in England, we have not the glaciers to assist in their transportation. It has been imagined, that these fragments and beds of gravel were deposited in their present positions, before the intervening vallies were scooped out. But any subsequent deluge, sufficiently powerful to scoop out vallies, must also have swept away the loose stones on the surface. We must therefore admit, either that the water of the deluge covered the earth for some time, during which period the stones and gravel were deposited, and, on retiring rapidly, excavated the softer strata into vallies; or that a great change has since taken place in the level of particular situations, by elevation or subsidence.

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* Those depressions in a range of mountains, which offer the easiest access in crossing from one valley to another, are in the Alps called *Cols*. I observed that these cols were all in the softest beds; and their formation admits of an easy explanation by diluvial action. See Plate 2. fig. 2. "A range of mountains with their beds highly elevated, is extended from *a* to *d d*. At *c c* the beds are of very soft slate or shale, which has been excavated so as to offer a passage over the range, though the highest part is several thousand feet above the valley. Such is the Col de Balm above Chamouni. The beds probably extended, at the period of their elevation, in the direction of the dotted lines. These cols could not be formed by rivers, as very little water flows from them. The valley of Derwent (see Plate 4. fig. 1. between the hills 8 and 6,) was evidently formed by the erosion of water, and not by the elevation of its sides; as the beds on each side are the same.

Many facts appear to prove, that both local and general changes have formerly been effected in the relative level of the land, and the bed of the ocean. The alternations of marine and freshwater formations below the chalk strata, offer a proof of this; and the occurrence of freshwater shells, and the remains of tree-ferns and marsh-plants, in the coal strata, prove the vicinity of dry land, and that these strata were not deposited under a deep sea, as appears evidently to have been the case with the chalk strata, and also with the magnesian limestone, that immediately covers the coal strata. But not to go so far back in our researches, we have a present proof on the shores of England, of the change which the level land has undergone. A submarine forest, extending far into the sea, may be traced at low water on many of our coasts, and particularly on those of Yorkshire and Lincolnshire. The trees are broken off near the roots, but their stumps are erect, and indicate that they are in the position in which they have formerly grown. This fact alone may serve to show, that the relative level of the dry land and the ocean has not always been the same that it is at present, and may induce us to admit, with less reluctance, the successive subsidences and emersions of the ancient continents, which the alternation of marine with freshwater strata, directly indicate.

It will not be foreign to the present subject to state, that, from recent accounts of travellers who have visited Thibet, it appears that bones of horses and deer are brought down by avalanches from the Himmaleh mountains, at the height of sixteen thousand feet, and above the region of eternal snow. Now if this fact be well established, it would indicate, either that these bones had been deposited there by a deluge, or that the mountains had been raised, since the Asiatic continent was peopled by land quadrupeds analogous to, if not identical with, existing species; for it cannot be supposed, that horses and deer could have subsisted near the summits of these mountains, surrounded by snow, and far above the region of vegetation. If ancient traditions could be relied upon with as much certainty as the records of nature imprinted on the crust of the globe, we might cite the fact of ancient continents having sunk down since the world was peopled by the human race. Plato, in his dialogue entitled *Timæus*, says, that Solon received an account from the priests of Sais in Egypt, that there was formerly a vast country called the Atlantades, situated beyond the Straits of Gibraltar, the inhabitants of which were highly civilized, and flourishing; but the whole country was engulphed in the ocean, during a violent earthquake.

The limits of an elementary treatise will not admit a greater space for geological theories, or for the further enumeration of facts, that indicate the former action of inundations on the surface of continents and islands, and the changes which have taken place in the relative level of the land, and the bed of the ocean. These facts must be admitted, notwithstanding the difficulties that may attend their explanation, for it is not a mere fiction of fancy, that

> "Earthquakes have raised to heaven the lowly vale,
> And gulphs the mountains' mighty mass entombed,
> And where the Atlantic rolls, wide continents have bloom'd." *Beattie.*

Yet whatever proofs we may have of such changes, they are so remote from our present experience, at least in this part of the globe, that we cannot avoid regarding them as more proper subjects for the poet, than for the sober records of the natural historian.

Before I conclude, it may be right to advert to an inquiry that has frequently been made—*What advantage can be derived from the study of Geology?*

The value of every science must ultimately rest on its utility: but in making the estimate, we ought not to be guided alone by the narrow view of immediate gain. The material universe appears destined to answer two important purposes: the first of which, is to provide for the physical wants of its various inhabitants. Now in relation to this purpose, the science which teaches us the structure of the earth, and where its mineral treasures may be found, can scarcely be deemed devoid of utility by a nation deriving so much of its comfort and wealth, from its mineral resources. But beside supplying our physical wants, the external universe is destined to answer a nobler purpose; its various objects appear intended to excite our curiosity, and stimulate our intellectual powers to the discovery of those laws, by which the successive events we observe in nature are governed. Without this excitement, man would for ever remain the mere creature of animal sensation, scarcely advanced above the beasts of the forest; and the universe would be to him a mute and unmeaning succession of forms, sounds, and colours, without connection, order, or design. In those sciences, which have attained the highest degree of perfection, the skill of the Creator, and the ends and uses of the different parts are most apparent. Geology has not yet made sufficient progress, to carry us far in this path of inquiry; but we see enough to discover, that the very disorder into which the strata on the surface of the globe are thrown, and the inequalities which it presents, are absolutely necessary to its habitable condition. The distribution of its mineral treasures, and particularly of coal, to the cold and temperate regions of the globe, is well deserving attention, and implies a prospective regard for the wants of civilized man: but a cold-hearted philosophy, under the sanction of a quaint expression of Lord Bacon,* has (to use the words of Dugald Stewart) " made it fashionable to omit the consideration of final causes entirely, as inconsistent with the acknowledged rules of sound philosophizing. The effect of this has been to divest the study of Nature of its most attractive charms, and to sacrifice to a false idea of logical rigour, all the moral impressions and pleasures, which physical knowledge is fitted to yield."

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* "Causarum finalium inquisitio sterilis est, et tanquam virgo Deo consecrata nihil parit."

Geology discovers to us proofs of the awful revolutions which have in former ages changed the surface of the globe, and overwhelmed all its inhabitants: it reveals to us the forms of strange and unknown animals, and unfolds the might and skill of creative energy, displayed in the ancient world: indeed, there is no science which presents objects that so powerfully excite our admiration and astonishment. We are led almost irresistibly to speculate on the past and future condition of our planet, and on man, its present inhabitant. What various reflections crowd upon the mind, if we carry back our thoughts to the time when the surface of our globe was agitated by conflicting elements, or to the succeeding intervals of repose, when enormous crocodilian animals scoured the surface of the deep, or darted through the air for their prey;—or again, to the state of the ancient continents, when the deep silence of nature was broken by the bellowings of the mammoth and the mastodon, who stalked the lords of the former world, and perished in the last grand revolution that preceded the creation of man. Such speculations are somewhat humbling to human pride on the one hand, but on the other, they prove our superiority over the rest of the animal creation; for it has been regarded by the wisest philosophers in ancient times, as a proof of the high future destiny of man, that he alone, of all terrestrial animals, is endowed with those powers and faculties, which impel him to speculate on the past, to anticipate the future, and to extend his views and exalt his hopes, beyond this visible diurnal sphere.

CHAPTER XX.

AN OUTLINE OF THE GEOLOGY OF ENGLAND AND WALES.

Geology of England and Wales.—The principal mountain range on the western side of the island denominated the Great Alpine Chain.—Divided into three groups or ranges.—Mineral treasures of the Devonian range.—Mountains of the Cambrian range and principal mineral treasures.—Extent of the Northern range.—Structure of the calcareous mountains explained by a section of England.—Mountains surrounding the Lakes.—Branch from the Northern range extending into Derbyshire.—These three ranges comprise the Alpine districts.—The middle district, coal fields in it enumerated.—This district in some parts covered by red marle and sandstone containing rock-salt and brine springs.—Primary rocks and ancient trap rocks, appear in the middle district, at Charnwood Forest, in Warwickshire, Gloucestershire and Somersetshire.—The upper calcareous district contains no beds of good coal nor any metallic veins.—Extent of the Magnesian limestone bordering the coal strata.—Extent and duration of Lias limestone through England.—Range of Oolite limestone through England and its abrupt termination.—Strata between the oolite and chalk.—Extent of chalk in England.—Tertiary formations covering chalk.—Alluvial and diluvial depositions.—Subterranean and submarine forests.—Thermal waters of England.—Observations on the total thickness of the different rock formations of England.—On coal districts concealed by upper calcareous strata.—On the cause which prevented the further extension of the oolite and lias to the north-west.

The shape of islands and continents, is generally determined by the ranges of primary and transition mountains that traverse them; these have been compared to the skeletons, on which the other parts of a country are constructed.

The length of Britain is determined by different groups of mountains, which viewed on a large scale may be regarded as one mountain range, extending north and south (with its ramifications) along the western side of England and Wales, from Cornwall to Cumberland, and from thence to the northern extremity of Scotland. All the highest mountains in England and Wales are situated in this range, which, in reference to our island, may be called the great Alpine chain. This chain is interrupted by the intervention of the Bristol Channel, and the low grounds of Lancashire and Cheshire, which divide it into three groups or ranges; these, for the sake of distinction, may be denominated the Devonian range, the Cambrian range, and the Northern range. They form the *Alpine districts* of England (coloured red in the map.) The mountains of the great Alpine chain from Cornwall to Cumberland, are composed of primary rocks and of other rocks, which belong chiefly to the class of transition rocks, described Chap. VII. Those parts in which the primary rocks chiefly occur, are shaded by lines. In some few parts east of the Alpine district, the primary and transition rocks also make their appearance, uncovered by the secondary strata. A range of primary and transition mountains appears once to have extended from the Devonian range, in a north-east direction, into Derbyshire: the transition mountains of that county, the Charnwood Forest hills, the sienitic greenstone of Warwickshire, the transition rocks of Dudley, the Malvern Hills, and the trap rocks of Gloucestershire, Somersetshire and Devonshire, were probably parts of one range, and were much loftier than at present.

It was this range that appears to have determined the extent of our island in that direction, and to have formed the western border of an ancient sea or lake, in which the upper calcareous strata were deposited. It appears also to have determined the extent of the upper calcareous strata, that cover the eastern side of England, and are bounded by the line A' A A. This boundary marks the direction of a range of calcareous hills, that extend through England in a waving line, from the western extremity of Dorsetshire, to the eastern side of the county of Durham. East of this line, there are no beds of mineral coal found in any part of England. Between the line A A A and the Alpine districts (coloured red,) we have the under secondary strata (coloured green.) All the principal coal formations in England occur in different parts of this district, which, for the sake of distinction, we shall call the *Middle district*: it is however partly covered by beds of red marle and sandstone. *The upper calcareous district*, east of the line A A A (and coloured yellow in the map,) is in some parts covered with beds of clay and sand of a more recent formation, belonging to the tertiary strata ; they are bounded in the map by the lines o o o o. Other low parts of this district are covered by alluvial depositions.

England and Wales may thus be divided into three geological districts : the Alpine district, the Middle district, and the Upper Calcareous district ; the latter partly covered by tertiary formations. Each of these districts has its appropriate characters and mineral productions. In order to give the reader a clear idea of the relative position of the rocks and strata of these three divisions, let him take three sheets of paper, and cut out the form of England in each. Let the lower sheet be red ; cover this with green paper, cutting out all the parts on the western side, which will leave the parts marked red in the map uncovered, and also the small parts where the Malvern Hills and Charnwood Forest hills are situated. Cut out the third sheet of yellow paper, so that its edge may correspond with the line A A A. Then cut out pieces of darker coloured paper, and place them over the parts marked 2 2 2. for the tertiary strata ; and sprinkle sand on the parts marked 1 1 1. for alluvial and diluvial depositions ; raise the western edge a little, so as to make the sheets of paper incline to the south-east ;—and we shall then have a model of the geology of England, which would be complete, provided we could raise the parts marked red above the level of the green paper. The red paper, which spreads under the whole and represents the primary and transition rocks of the Alpine districts, may be conceived to extend under the sea, and to rise again in Ireland, France, Sweden, and Germany, and thus to be connected with all the granitic ranges of the old continent. It is scarcely requisite to remark, that in presenting a general view of the arrangement of the different classes of rocks in this manner, the partial wavings or irregularities of the strata, and the inequality of surface presented by hills and valleys, must be necessarily disregarded.

In the whole of the Alpine district, except that part of it which forms the Devonian range, the rocks of granite are deeply covered by slate rocks, and only make their appearance in a few situations.

To begin our description with the Devonian Range,—suppose the geologist to be landed on the steep granite cliffs at the Land's End in Cornwall; he would perceive west of him the rocks of granite, called the Long Ships, and the more distant Scilly Islands, which were once probably united to Cornwall. This part of Cornwall is composed chiefly of granite, which sometimes passes into porphyry. The granite is frequently covered by slate rocks. A silvery kind of slate, provincially called Killas, appears to occupy the place of mica-slate. At the Lizard Point, the granite is covered by mica-slate, beds of serpentine, and diallage rock or crystallized serpentine.

From the Land's End to Dartmoor, the traveller will pass over a dreary ridge of granite, covered mostly by slate rocks. The surface of the country is every where broken by mines; there is scarcely a tree visible, and the hills are too low to produce any picturesque effect.

At Dartmoor, in Devonshire, the granite rocks approach to a mountainous character, rising to the height of one thousand seven hundred feet above the level of the sea. Rocks of transition limestone occur near the feet of the granite mountains, and also on the southern coast of Devonshire.

The western boundary of the Devonian range is composed principally of greywacke slate, and transition limestone, which extend along the side of the Bristol Channel, into Somersetshire. The Mendip and Quantock hills are part of this range.

Steatite or soap-rock, much valued in the manufacture of china, is found at the Lizard Point. Kaolin, or decomposed felspar, employed also in the manufacture of china, and for the finer kinds of pottery, is afforded by the granite rocks of Cornwall. Slate and marble are supplied from many parts of theDevonian range: but the treasures for which this part of England is most distinguished, are the ores of tin and copper. For the former, our island was visited by the first commercial nations of antiquity. The mines of tin are far from being exhausted; but the ore must have been more abundant formerly, than at present. This is evident, from the pebbles of tin ore, found a little under the surface in the alluvial depositions of Cornwall. Tin ore or tin stone as it is called by mineralogists, is extremely hard; and there can be little doubt that these water-worn fragments once formed a part of regular veins, which intersected mountains that have been decomposed and worn down.

Beside copper, tin, and lead, this range contains ores of silver, cobalt, bismuth, manganese, antimony, zinc, and iron. Pieces of native gold are occasionally discovered in the sands of rivulets, in a similar situation to stream tin; some of these pieces are as large as a field bean. All the known metals are found in Cornwall, except platina, mercury, molybdena, tellurium, tantalium, columbium, and cerium.

The annual value and produce of the copper and tin from the mines of Cornwall and Devonshire, on an average of several years, may be stated at 75,000 tons of copper ore, value 800,000*l.* sterling; 3250 tons of metallic tin, value 227,000*l.* sterling.

Crossing the Bristol Channel, we come upon the Alpine district of the Cambrian range, which comprises nearly the whole principality of Wales, and a part of Monmouthshire, Herefordshire and Shropshire. Nearly the whole of this district is composed of slate rocks, transition limestone, and graywacke, and that mode of graywacke, which from its red colour, has been called by English geologists Old red sandstone. The borders of the Bristol Channel, along Pembrokeshire, Caermarthenshire, and Glamorganshire, are covered by coal strata, described p. 113. This part properly belongs to the lower secondary strata of the middle district. The coal strata rest on beds of transition limestone, which rise from under them, on their northern outcrop. The eastern side of this dictrict, as far as Wenlock in Shropshire, is composed of various beds of the old red sandstone, which in some parts passes to the state of common graywacke, and in other parts forms an imperfect porphyry. These beds cover the greater part of Herefordshire and the western border of Monmouthshire; the lowest beds of transition limestone, form a narrow range extending from Caermarthen to Wenlock. Nearly the whole of Caermarthenshire, Montgomeryshire, and Radnorshire, are occupied by mountains of slate and graywacke, which present little variety of character; but near the town of Old Radnor, there are rocks of diallage, and further west, at Llandgley, there is a low range of craggy rocks, composed of cellular claystone, which bears a strong resemblance to some varieties of lava. A similar rock covers some part of the Wrekin and Caer Caradock Hills of the trap formation in Shropshire.

In Merionethshire we meet with other rocks, particularly of porphyritic trap, composed chiefly of feldspar, which are similar in composition to many ancient rocks of igneous origin, in the South of France. (See Chap. IX. with a reference to Cader Idris, p. 153.) Granite occasionally makes its appearance at the feet of some of the Welsh mountains; and on the western side of the Isle of Anglesea, there are rocks of serpentine, talcous slate, and mica-slate.

Snowdon in Caernarvonshire, and other mountains in its vicinity, rise from three thousand four hundred, to three thousand five hundred and seventy feet above the level of the sea, or above three hundred feet higher than any of the mountains in Cumberland. A magnificent view of that part of the Cambrian range which extends through Caernarvonshire, is seen from the southern point of the Isle of Anglesea, on the entrance of the Menai: here the whole of the Snowdonian mountains may be comprised in one view, from Penmanmaur on the northern coast, to the conical mountains called the Rivals, on the furthest southern extremity of the county, Snowdon rising immediately in the midst of this range.

In the counties of Flint and Denbigh, there is a large formation of mountain or transition limestone, resting upon thick beds of conglomerate, which occupy the same relative position as the red sandstone in Monmouthshire; thus separating the mountain limestone from the slate rocks. The limestone mountains of Denbigh and Flintshire contain rich mines of lead ore. On the north and east, the feet of these mountains are covered with coal strata. Roof slate of a good quality, and ores of lead and zinc, form the principal mineral treasures of the Cambrian range,—

except coal, which will be afterwards noticed. Some of the slate rocks contain mines of copper ore; and the Paris mine, in the Isle of Anglesea, was formerly the most productive copper mine in Great Britain; but it is now nearly exhausted. For an account of the serpentine in the Isle of Anglesea, see pages 87, 88.

Crossing the plains of Cheshire and the lower part of Lancashire, we come upon the transition limestone of the northern range. Near Clithero, in the latter county, where the beds are much contorted, this limestone is fully developed in the northern range, and extends with little interruption from Clithero, through Craven in Yorkshire, and the western parts of Durham and Northumberland, and thence into Westmoreland and Cumberland. The numerous beds of this limestone alternate with graywacke slate, and what may properly be called graywacke sandstone. The lowest bed generally rests on slate, but sometimes a bed of red sandstone or conglomerate is interposed. The slate lies conformably with the limestone; but being divided into thick plates, which are nearly vertical, they have frequently been described as vertical strata, supporting nearly horizontal strata of limestone. Their true position is represented in Plate 3. fig. 1. *d. d.* The mountain or transition limestone of these counties, forms the base of many lofty mountains, that are capped with the lower strata of the coal formation.

Ingleborough Hill in Yorkshire, and Cross Fell in Cumberland, present a complete exhibition of the structure of the calcareous mountains of this range. This will be better understood by a reference to Plate 7. fig. 1. which is a section of England, from the German Ocean to the Irish Channel, through the counties of Durham and Cumberland.

The magnesian limestone B, rises above the German Ocean A, and covers the eastern border of the great coal-field of this district. The coal strata C C, are represented dipping eastward; they are in some parts deranged by dykes of basalt, one of which, the Burtreeford dyke, throws up the strata one hundred and eighty yards. As we advance towards the summit of Cross Fell, 5, we pass over the lower beds of the coal formation; they terminate on the summit of this mountain, which is capped with a bed of coal. The middle and lower parts of the Cross Fell are composed of beds of transition limestone, D D, alternating with graywacke and sandstone, which rest at its base on slate, E. The slate is continued westward, till it is interrupted by nearly vertical beds of trap and sienite. In the Vale of Eden, the subjacent rocks are covered by beds of conglomerate, or of red sandstone, F, of which the hill called Penrith Beacon, 4, is composed. The lofty mountains that surround the lakes of Cumberland and Westmoreland, are skirted by beds of lower transition limestone, H. The highest mountains of this group are Helvellyn 3, Skiddaw 2, Sea Fell 1. On the western border of this group we meet with transition limestone, and siliceous sandstone dipping westward; then succeeds the coal strata of Whitehaven, C, which dip beneath the sea, and are in some parts covered with magnesian limestone, B.

To return to Cross Fell. The transition limestone, beside being divided into numerous beds, by beds of graywacke and sandstone, has also irregular beds of basalt interposed between the strata. The most considerable of these beds is called the Great Whin Sile; it is in some parts sixty yards thick. Masses of columnar basalt also occur on the surface. According to the account of the strata of this country, given by Mr. Westgarth Forster, the total number of beds of limestone is eighteen, and their total average thickness about one hundred and fifty yards. The basaltic dykes of this district have been noticed in Chap. IX. In Derbyshire and Wales, the beds of transition limestone are fewer and thicker, than those of Durham and Northumberland. Cross Fell is the highest calcareous mountain in Great Britain, rising two thousand nine hundred feet above the level of the sea. From its summit, both the Irish Sea and the German Ocean may be seen.

The Alpine mountains surrounding the lakes are composed chiefly of slate, containing beds of good roof slate, graywacke, flint slate, porphyritic feldspar, and sienite. Granite occurs in some parts of the group, particularly near Shap, and at Caldbeck Fell, under Skiddaw, and in the mountains on the west side of Wast Water. The mountains of this group bear a striking similarity of composition to those of North Wales, and like them contain rocks of porphyry, which appear nearly allied to ancient volcanic rocks. In some situations they assume a columnar structure. The most remarkable of those rocks are described pages 144 and 145.

There are in some of these mountains, beds of red unctuous ferruginous clay and iron-stone. In one of these beds, above Seathwaite in Borrowdale, is found the justly celebrated black-lead, or graphite, which is the best that has hitherto been discovered. It occurs in irregular nodules, intermixed with green earth, quartz, and calcareous spar. I was informed at the mine, that the smaller pieces sell for seventy pounds per ton, and the larger for forty shillings per pound; and that black-lead to the value of one thousand pounds, had been obtained in one day. The bed above the ferruginous bed containing the black-lead, is composed of gray porphyritic felspar; the bed under it, approaches to a green slate (clay-slate.) The black-lead occupies what is called a vein, on the lower side of the ferruginous bed: it is generally narrow, but opens out into wider spaces, filled with this valuable mineral. The same bed of ferruginous clay, I have ascertained, ranges through the adjacent manors, where it is probable black-lead might also be found, were proper search made for it.

The highest mountains of Cumberland, Westmoreland, and Craven in Yorkshire, rise about three thousand feet above the level of the sea. Snow remains on their summits and northern declivities to the middle of June, and in some instances has continued the whole year.

A branch from the Northern range extends into Derbyshire and the north part of Staffordshire, the transition or mountain limestone of Yorkshire being continued into those counties; but the continuation is apparently interrupted by the lower beds of the coal formation, that cover it from Skipton to near Castleton. The limestone of Derbyshire is divided into four beds, by intervening beds of basaltic amygdaloid; in all its characters it resembles the transition limestone in other parts of the Northern range, and is described p. 101, 156. The transition limestone of the Northern range is rich in ores of lead and zinc.

The middle district of England, (coloured green in the map,) is comprised between the Alpine district on the west, and the Upper Calcareous district (coloured yellow) on the east. In this district, all the principal coal-fields of England and Wales are situated. The strata of the middle district are those described as the lower secondary strata, Chap. IX. They are principally siliceous and argillaceous, and the fossil remains are chiefly vegetable. Few beds of limestone occur in this division. The general dip of the strata in the northern and midland counties, east of the line c c c, is to the east or the south-east, and they dip under the calcareous strata A A. The latter cover their eastern border unconformably, as represented Plate 7, fig. 1. B. and Plate 1. fig. 3. The more western and southern parts of the division (coloured green) are frequently covered by extensive beds of gravel, and by red marle and sandstone; and in some parts of this division primary and transition rocks rise to the surface, as at Charnwood Forest in Leicestershire, and the Malvern Hills in Worcestershire.

Beginning from the north, strata of the coal formation extend on the eastern side of Northumberland and Durham, from Berwick-on-Tweed, to the river Tees; but from thence to the river Air (near Leeds), only the lowest beds of the coal formation occur, which contain but little workable coal. The Yorkshire and Derbyshire coal-field commences a little north of Leeds, and extends in breadth east and west about twenty-five miles, from Halifax to Abberford, and in length about seventy miles, from Leeds to near Nottingham and Derby. The breadth decreases southward, being little more than twelve miles in Derbyshire.

South-west of Derbyshire there are a few small coal-fields near Ashby-de-la-Zouch, and near Tamworth, Atherstone, and Coventry. The latter coal-field is the most southern situation in which mineral coal has been discovered in the midland counties.

On the north-west side of England, there is a small coal-field bordering the sea in Cumberland, which extends from Whitehaven, to the north of Maryport. This coal-field, though small in extent, contains seven beds of excellent workable coal. From its contiguity to the sea, and its remoteness from other coal-fields, it may be considered, in proportion to its extent, as one of the most valuable coal districts in England. In one mine, the coal is wrought at the depth of two hundred and ninety-eight yards. The workings of some mines have been extended under the sea. The next considerable coal-field is that of Lancashire: it is separated from the Yorkshire coal-field by a range of lofty hills, on the borders of the two counties, extending on the west side of Colne, to Blackstone Edge, and from thence to Axe Edge, on the border of Derbyshire. These hills are composed principally of millstone grit and shale, but are not covered by coal strata. On the western side of these hills, the coal strata of the Lancashire coal-field commence, dipping westward; but they are broken and deranged by numerous faults. The principal beds of coal are,—one of six feet in thickness, and a lower one called the three-quarter bed. In some parts the sandstone strata are of a deep red colour. The breadth of this coal-field from Macclesfield to Oldham, does not exceed five or six miles; but from Oldham, it extends westward to Prescot near Liverpool, and from Prescot it extends in a north-east direction to Colne.

Not far from the southern extremity of the Lancashire coal-field, there is a small but valuable coal district, which supplies the potteries near Newcastle in Staffordshire; this may be properly considered as an extension of the Lancashire coal-field. The next important coal-field is that of Dudley and Wolverhampton; it is about twenty miles in length, and varies in width from four to seven miles. It contains the thickest bed of coal in Great Britain. (See page 115.) There is a narrow coal-field on the north eastern border of Wales, extending from Mostyn in Flintshire, to Chirk in Denbighshire. There are also a few smaller coal-fields on the north eastern side of Herefordshire, which extend into Shropshire. The Clee Hills near Ludlow contain, on their sides, two or three small detached coal basins. The summits of these lofty hills are capped with basalt.

The coal basin of the Forest of Dean, is the next considerable repository of coal: it presents perhaps the most perfect model of a coal basin, of any in Great Britain; the coal strata occupy a space of about ten miles in length, and six in breadth: the millstone grit, and the transition limestone, on which they lie, may be distinctly observed cropping out on its northern and western boundary.

In Somersetshire and Gloucestershire, there is a considerable coal-field on each side of the river Avon; its greatest extent is about twenty miles, and its greatest ascertained breadth about eleven miles; but it is covered in many parts by the upper secondary strata, consisting of red marle and lias. The deepest coal mine in England is in this coal-field; the depth of the pit at Red Stock near Bath being four hundred and nine yards.

The greatest repository of coal in our island, is that which extends on the northern side of the Bristol Channel, one hundred miles in length, and varying in breadth from five to twenty miles. It has been already noticed, Chap. VIII, pages 113 and 135.

A considerable part of the middle district, (coloured green in the map,) which is not occupied by the coal formations above enumerated, is covered by the red marle and sandstone described in Chap. IX. As the sandstone of this formation often covers the coal strata, it becomes an object of great interest to landed proprietors, in the midland counties, who have estates at no great distance from the coal districts, to ascertain whether coal may not extend under the red marle and sandstone. Some observations on this subject are given, (pages 129 and 130,) which the author is persuaded deserve the attention of landed proprietors. The search for coal under the red marle and sandstone in Somersetshire, has been eminently successful; and coal has in some instances been found, by sinking through both lias and red sandstone.

The principal repositories of rock salt, and the strongest springs of brine, are situated in the red marle of Cheshire, and near Droitwich in Worcestershire. (See pages 183 and 185.) In this formation, the principal beds of gypsum are found: it is frequently associated with rock salt. (See Chap. XI.)

One of the most remarkable features of the middle district, is the occasional occurrence of considerable rocks of granite, slate, and sienite, belonging to the class of primary or transition rocks; they rise through the secondary strata, and appear, from various circumstances, to have once occupied a considerable portion of the midland counties, extending from Leicestershire to Warwickshire, Worcestershire, Gloucestershire, Somersetshire, and Devonshire. The rocks of porphyry, sienite, and granite in this district, like many similar rocks that have been observed in other parts of the world, appear to be closely associated with, and to pass into rocks of the trap formation, allied to basalt and volcanic rocks. (See an instance of the passage of granite into basalt, page 142.) The Charnwood Forest hills in Leicestershire, extend about ten miles from S.E. to N.W. rising from six to eight hundred feet above the circumjacent country; they represent in miniature the mountains of North Wales, and those in the vicinity of the Lakes. They are composed principally of flinty slate, roof-slate, porphyritic trap, porphyritic greenstone, sienite, and granite. No organic remains have been observed in any of the Forest rocks, nor in the slate quarries which have been extensively worked for many years. Veins of white quartz containing chlorite intersect these hills, particularly in that part between Bardon Hill and the town of Whitwick. No appearance of any metallic substance occurs in these veins,* nor is pyrites found in any of the rocks which I examined: a rock containing a great quantity of yellow mica, at a place called Basil Wood, is an imperfect mica-slate, passing into gneiss. The roof-slate is confined principally to the eastern side; and on this side the beds are more regular, and rise at a very elevated angle to the south-west. The slaty cleavage of the stone is nearly at right angles with the direction of the beds. All the rocks of this district, except the porphyritic rocks on the west side, have a tendency to assume pyramidal forms; and the stone divides into trapezoids with smooth faces, by which they may be distinguished at a distance, from any other stones in that part of England.

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* Except a few spangles of micaceous iron ore.

The changes by which the different kinds of rock pass into each other, are similar to those described by D'Aubuisson in the department of La Doire.[*] In the same rock, the upper bed will sometimes be porphyritic and the next compact; and sometimes from the same bed, small specimens might be broken, which will present the two characters on the opposite sides. The large-grained sienite of one rock, becomes smaller-grained in another; and in the adjoining rock it will be porphyritic, and pass by gradation into flinty slate with small crystals of felspar.

Veins of dark and nearly compact greenstone, intersect the sienite at Mount Soar Hill. The sides of the vein are intermixed, and closely united with the rock.

The granitic rocks of Mount Sorrel are separated from the slate rocks by a plain, called Rokeby plain, which prevents their junction from being traced on this side; they have a lower elevation than the slate, which is inclined, as if it rose from under them. Bardon Hill is composed of sienitic porphyry; Beacon Hill is composed of flinty slate, and porphyry slate containing crystals of felspar. These are the two highest hills in the Forest. The gradations from sienite to porphyry slate and flinty slate, are frequent on the western side of the Forest. The only mineral substances obtained from these hills is roof-slate, paving-stones, and a species of whetstone or hone; this is not found in a regular bed, but in fragments under the soil. The beautiful green and red sienite at Markfield Knowl might be employed for durable ornamental architecture; large pyramidal blocks are scatter-

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"Le passage d'une de ces variétés de roche à l'autre, provenant de la différence dans les proportions des principes, est aussi brusque qu'il est fréquent. Dans le distance de quelques pas on voit tantôt un schiste presque entièrement formé de feldspath, tantôt très abondant en quartz, tantôt, formé de talc presque pur."—*Journal des Mines*, Mai 1811.

ed over the hill; and were a quarry opened near the summit, the stone might probably be raised in large masses at a small expense.

The porphyritic rocks near Whitwick, particularly one called Sharpless, are composed of a dark purplish gray compact porphyry slate; it contains numerous crystals of quartz, and some imperfect garnets. The rocks on this side of the Forest are singularly shattered, and present deep perpendicular fissures, in some instances covered by transverse stones of immense size; they form piles of shapeless ruins, showing the devastation of the elements, and the effects of all-destroying time.

I have been more minute in the description of this part of England than may appear consistent with the mere outline of its geology, which I proposed to give; but so little was known respecting the mineralogy of these hills, though in the centre of the island, that I trust I shall be excused for this deviation. The country presents few scenes to allure the picturesque traveller, and the surface is now nearly concealed by plantations and inclosures. The observations were made during a mineralogical examination of some of the manors on the Forest, for the late Marquis of Hastings in 1812.

But it is the relation of these hills with the surrounding strata, that is most interesting to the geologist. On the northern side, at Grace Dieu, are strata of transition limestone, which rise gently to the Forest hills, and are connected with a series of rocks of the same formation, passing in a northerly direction by Ticknall and Breedon, and evidently connecting this limestone with that of Derbyshire. A little north of this, there are coal strata rising at an elevated angle, not more than 800 yards distant from the Forest rocks. On the north-west side of the range, there are thick beds of conglomerate, evidently formed of fragments of the Forest rocks: these conglomerate beds extend far northward. Between the elevated coal strata, and the Forest rocks, there are horizontal strata of the red marle and sandstone formation. The same sandstone covers the nearly vertical beds of slate at the Swithland quarries, and extends on the eastern side of the range, where it is covered with lias limestone.

The relative position of these different formations will be better understood by referring to Plate 2. fig. 4. *b b.* rocks of granite, sienite, and porphyry; *c c.* slate rocks; *d d.* coal strata rising towards the Forest rocks; *a a a.* nearly horizontal strata of sandstone, covering part of the Forest rocks; E, lias covering the sandstone. This section is not taken through the highest part of the range, but leaves Bardon Hill and Beacon Hill to the left. This arrangement of the strata, proves that the beds of sandstone, *a a a*, were deposited after the elevation of the beds of granite and slate, (See pages 166 to 168. Chap. X.) where it is inferred that the granite of this range is more ancient than the granite of the Alps. Taking Charnwood Forest as a station, from whence we would examine the geology of the central parts of England, we find no rocks on the northern side, in Derbyshire, Nottinghamshire, or Yorkshire, which can claim relationship with those of the Charnwood range, except it be the basalt of Derbyshire. The sienite and porphyritic trap-rocks on Charnwood Forest, sometimes approximate in appearance to basalt; and it is not improbable that future observations may establish a close connection between these rocks. The transition limestone, which approaches the Charnwood Forest hills on this side, is a continuation of that of Derbyshire. Turning to the south-west, we find rocks of the Charnwood Forest range appearing above the surface, on the road to Hinckley; and it can scarcely be doubted, that the green-stone and trap and quartz rock, near Atherstone and Nuneaton, are a part of the same range: they are identical in composition, and divide into the same trapezoidal fragments. From Nuneaton to Dudley and Bromsgrove Lickey, on the west of Birmingham, the surface is covered with the red sandstone; and no accurate search has been made to ascertain, whether any basaltic or granitic rocks appear *in situ.* At Bromsgrove Lickey, quartz-rock makes its appearance; and near Dudley, there are beds of transition limestone and basaltic rocks, which may probably be connected with those of Nuneaton.

The geology of the country round Dudley is too remarkable to be overlooked; it has been slightly noticed p. 100. The strata of transition limestone have here been subjected to a disturbing force, which has not only elevated them, but folded them round one of the hills, as if they had once been in a soft and flexible state; and the occurrence of basaltic rocks in the vicinity, seems to indicate the agent by which this had been effected. (See Plate 3. fig. 4.) *a*, *b*, two beds of transition limestone; the thickness of the outer is ten, and of the inner bed fourteen yards. In the hill A on the right, called Wren's Nest Hill, the strata are folded round the hill, as represented in the small compartment E, which is a ground plan. The beds of the same limestone at Dudley Castle Hill, B, are raised on each side of the hill, dipping in contrary directions. The great bed of Staffordshire coal, crops out at C, between Wren's Nest Hill, and Dudley Castle Hill. A hill capped with basalt is represented at D. The limestone is so nearly vertical at Wren's Nest Hill, that it is worked by horizontal shafts.

Proceeding westward from Bromsgrove Lickey into Worcestershire, the first granitic rocks we meet with, are those of the Malvern Hills. These hills extend for about ten miles from north to south; they rise above the level vale of the Severn, from eleven to fourteen hundred feet, and form a conspicuous feature in the geology of the western counties. These granitic rocks are composed principally of red felspar, and greenish hornblende, intermixed with quartz, mica, and epidote. In some parts, the hornblende prevails, and the rock passes to greenstone, resembling that of the trap formation. These rocks are rapidly disintegrating, and form a red soil. On the eastern side at the bottom, they are covered by red marle, which appears formed of the decomposed materials of these hills: on the western side, they are partly covered by transition limestone. The limestone in some parts, dips towards the granitic rocks, as if it passed under them. An experiment well deserves to be made, in order to ascertain the relative position of the limestone and granite in this place: it is not impossible, that the granite of the Malvern Hills, like that of Christiania in Norway, may cover transition limestone.

To the south-west of the Malvern Hills, we find trap-rocks ranging from Berkley towards Bristol. One of these rocks at Woodford Bridge, has been described p. 155. The surface of the land between Bristol and Bridgewater is much broken by the sea; but in that direction, on the north of Exeter, there are rocks called dunstone, and greenstone, of the trap formation; and from Exeter to Torbay, we meet with various groups of rock, of a similar formation. It well deserves attention, that all these rocks which have been described from Charnwood Forest to Torbay, are, with the exception of those of Dudley, partly surrounded by red marle and sandstone, which appears in a great measure formed of their decomposed materials. I observed a similar connection between red marle and granite, near Rouvray in France. (See pages 181, 189.) The part of England extending from Gloucester to Lancaster, which is represented in Mr. Greenough's map, as covered by red marle and sandstone, will probably be found on more minute investigation, to contain in various parts, beside the red marle, other formations. The red sandstone of Lancashire and Cheshire, often bears a different relation to the coal strata from that on the eastern side of England: it cuts off the coal like a wall of basalt.

The upper calcareous district on the eastern side of England, (bounded by the line A A A, and coloured yellow in the map,) comprises all the upper secondary strata, except the red marle and sandstone, called by English geologists the new red sandstone. It has been before observed, that no beds of good mineral coal, nor any workable veins of metallic ore, are found east of the line A A A in any part of England. The eastern boundary of this district, from the mouth of the Tyne to Nottingham, is composed of strata of magnesian limestone, described pages 176, 177. They form low ranges of hills, bordering the coal strata. The breadth of the magnesian limestone on the surface, through Yorkshire and Nottinghamshire, seldom exceeds seven miles. A little east of Nottingham, the lias limestone (which extends in a waving line from the Yorkshire coast, north of Gainsborough) approaches the termination of the magnesian limestone, and is continued along the line A A A from Nottinghamshire through Leicestershire, Warwickshire, to near Tewksbury; from thence it runs on the southern side of the Severn to Gloucester. From the vale of Severn, it is continued through Somersetshire and Dorsetshire, to Lyme (in the latter county,) where it is terminated by the sea. At its two extremities, on the Yorkshire coast and the coast of Dorsetshire, it forms lofty cliffs, which are remarkable for the variety of their fossils: the cliffs of Dorsetshire have furnished the most perfect skeletons of saurian animals that have yet been discovered. The lias, in its course from Yorkshire to Dorsetshire, rarely attains the elevation of two hundred feet. The beds of lias clay and limestone are the best characterized of any of the British strata: they are described at some length Chap. IX.

In passing through Somersetshire, the continuity of the lias is sometimes interrupted by intervening strata of other formations; but from Berkley in Gloucestershire, to Whitby in Yorkshire, it may be traced without any interruption, except what is occasioned by rivers that cut through it. The average breadth of the lias, from its western border, where the red marle commences, to its eastern border where it dips under the yellow limestone or oolite, varies from seven to ten or twelve miles. The situations where it may be best observed, are on the Dorsetshire coast east and west of Lyme, and at Whitby in Yorkshire. At Aust Passage on the Severn, it may be seen resting immediately on red marle; and the remarkable stratum, filled with the bones of fish and saurian animals, may be traced for a considerable distance. The sulphate of strontian, which is a rare English mineral, occurs here in considerable quantities in the red marle under the lias. Westbury Cliff, where the bone stratum again appears, is described p. 24. The lias limestone is quarried in various parts of its course for water-setting lime.

A range of lofty hills, composed of yellowish limestone of the oolite formation, (see Chap. XI.) extends from Dorsetshire to the north of Lincolnshire; oolite appears again on the Cleveland Hills in Yorkshire. The lower beds in these hills rest on lias.

The western boundary, as far as Nottinghamshire, is a little east of the line A A A. In Gloucestershire the hills of this range attain a considerable elevation, rising 900 feet or more above the vale of Severn.

They present their steep sides or escarpments to the west, and in standing on the summit of this range above the vale of Severn, a very interesting inquiry naturally suggests itself;—for here the beds of oolite terminate, and are no where found on the other side of the Severn, or in any part of England or Wales, to the west of the line A A A: the lias also terminates a few miles west of the Severn.* *Have the beds of oolite which form this range of hills, or have the beds of lias at their feet, ever extended much further than at present?* If they have not, we must then inquire, *by what cause has their further extent westward been impeded?*

Some detached hills of oolite occur in the vale of Severn, which have evidently been once continuous with the Cotswold Hills; but we have no reason to believe, that either the oolite or the lias have ever extended into any part of England west of the vale of Severn. In Ireland and in the Hebrides, the lias beds again make their appearance.

The beds of the oolite formation, with associated beds of clay, cover a considerable part of Gloucestershire, Oxfordshire, Northamptonshire, Rutlandshire, and the eastern side of Lincolnshire. They also extend into the east riding of Yorkshire, and terminate at the Cleveland Hills.

The oolite formation is divided into the lower, the middle, and the upper oolite;—the Portland stone belongs to the upper oolite. Between the middle and the lower oolite, there is a bed of clay, called Clunch clay, and Oxford clay; it is in some parts two hundred feet thick; many of its fossils are similar to those in the lias. Clunch clay covers a considerable part of the low land in Huntingdonshire, Bedfordshire, Oxfordshire, and may be traced southward through Wiltshire. (See p. 202.) Between the upper and the middle oolite, there is also another thick bed of clay, called Kimmeridge clay. (See p. 203.) For a more full account of the oolite formation, see Chap. XII.

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* A small patch of lias is found on the northern side of the Bristol Channel.

The animal remains in the various beds, from the magnesian limestone to the upper oolite, are exclusively marine, with the remarkable exception at Stonesfield, (See page 204;) but the strata between the upper oolite, and the greensand below chalk, contain river shells and bones of immense animals of the lizard family, some of which were more than sixty feet in length; and from the structure of their teeth, they are believed to have been herbivorous. The strata containing remains of freshwater animals, are described Chap. XIII. under the name of Purbeck beds, iron-sand, and weald clay.

A bed of sand and sandstone intermixed with green particles, lies under chalk, and accompanies it throughout the southern and eastern counties. The fossils in the greensand and chalk are marine. (See Chap. XIII.)

Greensand and chalk extend into Devonshire, where they occur detached from the great chalk formation, which begins east of Dorchester, and extends through part of Hampshire, Wiltshire, and Sussex; and through Berkshire, Buckinghamshire, and Hertfordshire, into Cambridgeshire and Suffolk. A small extent of chalk is exposed on the north coast of Norfolk, and it passes through the middle of Lincolnshire, on the eastern side of Yorkshire, to Flamborough Head, where it terminates. (See Chap. XIII.) The highest elevation which chalk attains, is at Inkpen Beacon in Hampshire, which is 1011 feet above the level of the sea. The remarkable derangement of the chalk strata, which has thrown the beds into a vertical position in the Isle of Wight (See page 241,) extends also through the Isle of Purbeck in Dorsetshire.

The chalk in the southern counties of England, is in some situations covered with thick beds of clay and sand, which belong to the tertiary formation. The organic remains found in these beds belong to different species from those in the chalk. The vale of Thames, between the chalk hills of Surrey on the south, and the chalk hills of Hertfordshire on the north, is covered with tertiary beds. (See the map, fig. 2 2 2.) The upper clay has been called the London clay; and the lower, the plastic clay: the lower clay extends westward, beyond the limits of the upper, as represented in the map. A small section across the vale of Thames from north to south, at the bottom of the map, will convey a clear idea of the relative position of the chalk, the plastic clay, and the London clay. In some situations, as at Hampstead on the north of London, and near Cobham on the south, the London clay rises above the Vale, to the height of 300 feet, and is covered with a stratum of marine sand, as represented at *d d.* in the section. Here we have one of the most simple cases of denudation. There can be but little doubt, that these caps of sand were once parts of one continuous stratum, but the intervening clay and sand have been subsequently excavated by diluvial agency. (See Chap. XIV. page 227.) Hampshire and the Isle of Wight are partly covered by tertiary strata, as represented in the map, and described pages 241 to 243, Chap. XIV., where a more full account of the geology of this part of England is given. The crag of Norfolk and Suffolk, which belongs to the tertiary formation, is described pages 237 and 238.

A considerable part of the counties of Norfolk, Cambridgeshire, and the eastern side of Lincolnshire, falls within the division of the map marked 1 1 1. The surface is fen land or marshes, gained from the sea in the Wash of Cambridgeshire, and the fen country of Lincolnshire; but a great part of Norfolk is covered by beds of gravel, sand, and clay, intermixed with fragments of chalk. Beds of flint-gravel, and fragments of ancient rocks (it has been before observed) are widely spread over the midland counties, but could not be introduced into the map.

There is a subterranean forest beneath a part of Holderness in Yorkshire, and in parts of Cambridgeshire and Lincolnshire, which extends eastward into the German Ocean below the low-water mark. The inland subterranean forest is also below the level of the sea.

A similar subterranean forest occurs on the Lancashire coast, north of Liverpool, and extends into the Irish Channel. These facts prove, that a considerable change has taken place in the relative level of the sea and land.

A subterranean forest on the Norfolk coast is noticed page 239. Mr. Taylor, who has examined its position, says, that it rests on the stratum called Norfolk Crag, and is covered by diluvium: he is inclined to refer it to the lignite formations of the tertiary strata. If this can be ascertained, the Norfolk subterranean forest, and the same forest which extends into Yorkshire, must be regarded as being of antediluvian origin. But these subterranean forests in England, deserve more attention than they have hitherto received from geologists; the period of their growth, and the causes by which they were submerged, are at present unknown. A similar subterranean forest extends into the sea on the coast of Flanders. *Have these forests been once united and afterwards separated by a subsidence, which formed the bed of the German Ocean?*

In a general view of the Geology of England, the thermal waters must not be neglected. The warm springs in Derbyshire vary in temperature from fifty-eight to eighty-two degrees, though each spring preserves the same degree of heat, except in situations where the waters have been intermixed with those near the surface. The effects of internal heat appear to extend under the whole district that contains basaltic amygdaloid or toadstone; for the rivers of this county are rarely frozen, except in still situations, and when the thermometer is little more than ten degrees above zero. A very sensible degree of warmth may be perceived in the water of the Crumford canal, between Matlock and Crich; and numerous exhalations from warm springs, may be frequently seen rising from the neighbouring hills. The warm springs of Bath, have a much higher temperature than those of Derbyshire. It has been remarked, that warm springs are confined principally to basaltic and volcanic countries. In Iceland, in the Azores, in Sicily, in Italy, in France, and various parts of Europe, not distant from volcanic or basaltic rocks, numerous warm springs exist; but in the whole of the United States of

America, where there are few basaltic rocks, warm springs are scarcely known.*

These remarks are confirmed by the situation of the warm springs in Derbyshire, surrounded by beds of basaltic rock nearly allied to lava. The hot springs of Somersetshire are situated on the western side of the island, not far from a range of basaltic rocks, extending from Berkley towards Bristol. It will scarcely be denied that the boiling fountains or geysers of Iceland, and the warm springs of Italy, Sicily, and Auvergne, derive their temperature from subterranean fire; and it is contrary to the established rules of philosophy, to multiply causes, and seek for other sources of heat, in the waters of Bath or Buxton.

The former have preserved their high temperature for two thousand years: hence it is obvious that they rise from a great depth, far below the effects of those changes, which take place near the surface. It is further remarkable, that the hot wells of Bath, and the boiling fountains of Iceland, both contain in solution siliceous earth, one of the most insoluble substances in nature. The similarity of their contents, affords a further confirmation that they derive their heat from the same cause; and we have every proof the subject will admit of, that this cause is subterranean fire.†

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* They are found in Bath County, Virginia, on the Wachitta in the Arkansaw Territory, and at New Lebanon, in the State of New York, &c. Trap rocks are not uncommon in the United States.—*Am. Ed.*

† Temperature of the Hot Waters in England, and some other parts of Europe.

	Fahrenheit.
Bristol	74°
Matlock	66
Buxton	82
Bath	112 and 116
Vichy (Auvergne)	120
Carlsbad (Bohemia)	165
Aix la Chapelle (Flanders)	143
Aix les Bains (Savoy)	117
Leuk (in the Haut Vallais)	117 to 126
Bareges (South of France)	120

For some account of the Thermal Waters in the Alps, see p. 79.

The total thickness of the different rock formations in England, from the marine sand on the top of Hampstead Heath, to granite, might be ascertained along any particular line of section with some degree of accuracy, did all the intervening formations occur under each other; but this is not the case. The rocks of the transition series, rarely occur in two distant situations in the same order of succession, and preserving the same degree of thickness. The secondary strata of the coal formation, preserve a considerable degree of regularity over the same district, but they almost always vary in remote districts. According to a section that was made across the coal-field of Derbyshire, from the magnesian limestone in the east, to the fourth limestone of Derbyshire in the west, the total thickness in a perpendicular line, may be about nine hundred yards. There are thirteen beds of coal, varying in thickness from six inches to eleven feet; the total thickness of coal is twenty-six yards.

The thickness of all the beds on the eastern side of the coal districts, from magnesian limestone to chalk, is a question of some interest to landed proprietors; as a knowledge of it would inform them, how far their estates were situated above the coal strata, supposing the latter to extend on the eastern side of the line A A A. According to an estimate by the Rev. J. Townsend, given in the former editions of this work, the total thickness of all the upper strata, including chalk and the red marle, did not exceed about one thousand seven hundred and ten feet: but more accurate observations of these secondary strata prove, that in many parts of England, their thickness is far greater than Mr. Townsend had estimated, and can scarcely be less than three thousand feet. There are, however, no known situations in England, where all the upper secondary strata, from chalk to the red marle or magnesian limestone, occur regularly under each other. Still the vast thickness of these calcareous beds, forbids the attempt to search for coal beneath them. There may, however, be parts situated east of the line A A A, where the upper strata are stripped off, or the lower coal strata forced up near the surface. An instance of this kind, well deserving attention, occurs in France, about twelve miles to the N. E. of Boulogne. A small portion of the regular coal formation, and the subjacent transition limestone, appears protruded through the chalk and oolite formations; and several beds of coal are brought near the surface, and are regularly worked. A few miles distant from these mines, I observed rocks exactly similar to the Kellaway rock.* No geologist would, from the nature of the surrounding rocks, have expected the occurrence of a coal-field in this situation. Should accident discover any similar protrusion of the coal strata on the eastern side of England, it may be well to take advantage of it; but without this, all expensive search for coal on this side of our island, will be attended with certain loss and disappointment.

In a preceding part of the present chapter, I have suggested an inquiry into the causes which have prevented the extension of the thick beds of oolite and lias, beyond the line marked in the map A A. It is evident, that the strata have not been discontinued by a failure of the materials of which they are composed; for they no where appear more fully developed, or in greater strength, than where they form the southern border of the Vale of Severn, and suddenly terminate. I am much inclined to believe, that we must seek for the cause of their discontinuance to the north-west, from a range of lofty mountains having once extended from the Malvern Hills (in a north-east direction) to Charnwood Forest, and in a south-west direction into Devonshire. The Malvern Hills, the Charnwood Forest hills, and the transition rocks of Somersetshire and Devonshire, are the only remaining nuclei of this range. This range probably formed the northern border of an ancient sea, of which the Forez mountains, and the Vosges in France, were the southern border. Were it not so, why should the lias and the oolite always terminate as they approach these rocks, both in England and France?

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* The coal mines are situated in the villages of Hardingham and Rety: there are five beds of coal, varying in thickness from three to five feet. The extent of the coal-field is about twelve hundred yards in length, and four hundred in breadth; the greatest depth is three hundred and thirty yards. The beds dip to the north. The three upper beds yield coal suitable for the forge; the lower are employed for burning lime.

If the Malvern range were once far loftier than at present, it might have formed part of a continent, or island, when all the land to the south and south-east was buried under the ocean. On this island may have lived the land quadrupeds, whose remains are found in the slate of Stonesfield (p. 204.) These bones, carried into the then existing sea by rivers, may have been borne further south by marine currents, and left among the calcareous and arenaceous depositions, of which the Stonesfield slate is composed. If we trace the upper calcareous strata from their inland termination to the sea, we must be convinced, they have once extended further to the south and east. The chalk cliffs at Dover, for instance, and the lias cliffs at Lyme, are evidently parts of more extensive strata, of which we find a continuation on the opposite coast of France; and the chalk cliffs at Flamborough Head, and the lias cliffs at Whitby, are parts of strata, which were continued into Denmark and Germany, where the same strata are again met with.

But though the upper calcareous strata evidently extended further than the coast of England on the south and east, there are no vestiges of these strata in England, west of the above line, except a small portion of lias at the feet of the transition mountains, on each side of the Bristol Channel. We have indeed reason to believe, that the lias and oolite never extended far beyond their present inland limits in England;* for we have decisive proof on the southern coast, that the lias beds did not extend further west on that coast, at the period when the green-sand and chalk were deposited; as we find the latter carried over the termination of the lias beds, to the red marle beyond them.* But I forbear to pursue such inquiries further; the object of the present chapter being to describe the Geology of England in its existing state. I leave to future geologists the task, if it can be accomplished, of tracing back the changes which the surface of the country has undergone, and of delineating it, as it appeared in its various progressive stages towards its present form.

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* It has been already stated, that the lias is found in the Hebrides, and on the north of Ireland; but it was probably deposited in a sea that was separated from the England lias by the Malvern range, and the mountains of Wales and Cumberland.

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* This will be better understood by referring to Plate 8. fig. 1. Were the beds *r r* carried over the terminal edges of the beds e e, we should be certain that the latter had not extended further, when the beds *r r* were deposited.

APPENDIX.

Page 131.—In the Chapter on Coal, I proposed to offer some observations in the Appendix, on the ineffective means hitherto adopted to prevent the frequent recurrence of fatal accidents in coal mines: but on due consideration, the subject is too important to be confined to a note, and would be misplaced in an elementary work on Geology. The number of lives destroyed by explosions in coal mines, has, I believe, been increased since the introduction of the safety-lamp; from causes which do not invalidate the value of the discovery, if its use were confined within the limits which its illustrious inventor must have proposed.

On Freshwater Fish and Shells.

In the second edition of this work I offered, in a note, some observations on the difficulty of determining whether certain animals were marine or freshwater, as it was possible that fish and many testaceous animals might be capable of living either in the sea or in rivers.

I stated a circumstance communicated to me by Mr Leckie, which proves that fish have greater facilities of change, than naturalists generally suppose. Dr MacCulloch has since paid attention to the subject, and ascertained that many species of fish will live equally well in fresh or salt water. The fact has been long known in Sicily, with respect to the mullet.

The lake of Lentini in Sicily is stocked with a sea fish called the Cefelo,—a species of mullet caught in the Mediterranean, and thrown into the fresh water of the lake, where they not only live, but increase greatly in size and improve in flavour, and are a considerable article of luxury in the island. This lake has no communication with the sea, and is filled chiefly with rain water.

On the Surface of the Moon.

Geologists have not hitherto regarded with due attention the physical structure of the moon: it is the only planetary body placed sufficiently near us to have the inequalities of its surface rendered distinctly visible with the telescope. Attendant on the earth, and having the same quantity of solar light, and nearly the same density, we may reasonably infer, that the mineral substances of which it is composed, do not differ essentially from those on the surface of our own planet. Astronomers now generally admit, that the moon is surrounded with a very clear atmosphere, but which is so low, that it scarcely occasions a sensible refraction of the rays of light, when it passes over the fixed stars. Many of the dark parts of the moon, particularly the part called *Mare Crisium*, appear to be covered with a fluid, which may probably be more transparent and less dense than water, as the form of the rocks and craters beneath it is seen, but not so distinctly, as in the lighter parts of the moon's surface. To examine the moon with a reference to its external structure, the defining power of the telescope should be of the first quality, sufficient to show the projections of the outer illuminated limb as distinctly, as they appear when the moon is passing over the disk of the sun, during a solar eclipse. With such a telescope, and a sufficient degree of light and of magnifying power, almost every part of the moon's surface appears volcanic, containing craters of enormous magnitude and vast depth; the shelving rocks, and the different internal ridges within them, mark the stations at which the lava has stood and formed a floor, during different eruptions; while the volcanic cones in some of the craters, resemble those formed within the craters of modern volcanos.

The largest volcanic mountain on the southern limb of the moon, (called by some astronomers Tycho, and by others Mount Sinai,) like the largest volcanic mountain on the earth, Chimborazo, and like Mont D'Or and the Puy de Dôme in Auvergne, has no deep crater on its summit. There are indeed the outlines of the crater, but it is nearly filled up; while from the foot of this mountain, diverging streams of lava flow in different directions, to the distance of six hundred miles. The largest currents of lava from lofty volcanos on the earth, generally issue from their flanks. The longest known current of modern lava is in Iceland; it extends sixty miles, but the volcanos in that island, bear no proportion to the magnitude of the lunar volcanos.

Geologists who are reluctant to admit the extensive agency of fire on the surface of the terrestrial globe, would have their difficulties removed, were they to study attentively the surface of the moon with a powerful telescope; for there we see the entire hemisphere of a planetary body, subjected to the agency of volcanic fire.

Since my return from the extinct volcanos of Auvergne, I have frequently amused myself in comparing the structure of parts of the moon's surface, with that of the volcanic districts in Central France; and I could scarcely avoid the conclusion, that the summits of many volcanic mountains in the moon, which reflect so much more light than the other parts, are, like those in Auvergne, composed of rocks analogous to white pumice or trachyte. I have suggested these hints, to direct the attention of geologists and astronomers to our attendant planet. *Is it inhabited? Is it passing to a habitable state? or does it present the ruins of a former habitable globe, torn by the powerful agency of volcanic fire?* Its appearance seems most to agree with the latter condition. Perhaps the perfection to which telescopes are advancing on the Continent, may enable astronomers at no distant period to answer these questions.

Orbicular Porphyry and Orbicular Granite of Corsica.

These are two of the most rare and beautiful rocks; but little is known respecting their relation with other rocks in that island. According to specimens of considerable size, which I have before me, this porphyry is composed of compact felspar, varying in colour from a greenish to a reddish brown. The globules vary in diameter from one-third of an inch to three-inches. The most perfectly formed globules have a small globule in the centre of each, from which ranges of minute globules diverge, giving to the large globules the appearance of a radiated diverging structure, more or less regular. In the smaller globules there are concentric circles, which disappear in the larger ones, except near their superficies. The paste in which globules are imbedded, contains also minute globules of lighter-coloured felspar, variously arranged. The larger globules are some of them elongated, as if they had been in fusion. The experiments of Mr. G. Watt on basalt, (See page 159,) elucidate the formation of orbicular porphyry.

The globular structure was probably developed during the semi-liquefaction of the mass, which formed globules, instead of perfect crystals, as in common porphyry. The globules in the Corsican porphyry, can be easily detached from the mass. Common porphyry, in which the imbedded felspar occurs in rounded spots, is called Variolite.

The orbicular granite of Corsica is better known in this country; it is a finely granitic rock, composed of white felspar, and blackish green hornblende, with grains of quartz. In this rock are numerous globules composed of concentric coats of hornblende and felspar, varying in diameter from one inch to three or four inches. In the centre of each globule, there is a particle of hornblende. The globules appear intimately united with the rock in which they are imbedded, and cannot be detached from it. The orbicular granite takes a more even polish than the porphyry, and is one of the most beautiful granitic rocks.

Height of some of the most remarkable Mountains and Hills in England and Wales.

	Feet.
Arbury Hill, Northamptonshire	804
Arran Fowddy, Merionethshire	2955
Arrenig, Merionethshire - -	2809
Axedge, Derbyshire - -	1751
Bagshot Heath, Surrey - -	463
Beacons, Brecknockshire -	2862
Bardon Hill, Leicestershire -	853
Beachy Head, Sussex - -	564
Black Down, Dorsetshire - -	817
Botley Hill, Surrey - -	880
Bow Fell, Cumberland - -	2911
Broadway Beacon, Glocestershire	1086
Brown Clee Hill, Shropshire -	1805
Cader Ferwyn, Merionethshire	2563
Cader Idris, Merionethshire -	2914
Caermarthen Vau, Caermarthenshire - - - -	2596
Cam Fell, Yorkshire, - -	2245
Capellante, Brecknockshire -	2394
Carnedd David, Caernarvonshire	3427
Carnedd Llewellyn, Caernarvonshire - - - -	3469
Carraton Hill, Cornwall -	1208
Cheviot, Northumberland -	2658
Coniston Fell - - -	2577
Cradle Mountain, Brecknockshire	2545
Cross Fell, Cumberland -	2901
Crowborough Beacon, Sussex -	804
Ditchling Beacon, Sussex -	858
Dover Castle, Kent - -	469
Dundry Beacon, Somersetshire	1668
Dunnose, Isle of Wight, - -	792
Dwggan near Builth, Brecknockshire - - - - -	2071
Epwell Hill, Oxford - -	836
Fairlight Down, Sussex - -	599
Farley Down (near Bath,) Glocestershire - - - - -	700
Firle Beacon, Sussex - -	820
Grasmere Fell, Cumberland -	2756
Greenwich Observatory, Kent -	214
Hathersedge, Derbyshire -	1377
Hedgehope, Northumberland	2347
Helvellin, Cumberland - -	3055
Hensbarrow Beacon, Cornwall	1034
Highclere Beacon, Hampshire	900
High Pike, Cumberland -	2101
Holme Moss, Derbyshire -	1859
Holyhead Mountain, Anglesea	709
Ingleborough Hill, Yorkshire	2361
Inkpen Beacon, Hampshire -	1011
Kit Hill, Cornwall - -	1067
Leith Hill, Surrey - - -	993
Landinan Mountain, Montgomery	1898
Llangeinor Mountain, Glamorganshire - - - -	1859
Long Mount Forest, Shropshire	1674
Long Mountain, Montgomery	1330
Lord's Seat, Derbyshire -	1715
Malvern Hill, Worcestershire	1444

	Feet.		Feet.
Moel Fammau, Denbighshire	1845	Sca Fell, (High Point,) Cumberland - - - -	3166
Nine Standards, Westmoreland	2136	Shooters Hill, Kent - -	446
Orpit Heights, Derbyshire -	980	Shunnor Fell, Yorkshire -	2329
Pendle Hill, Lancashire -	1803	Skiddaw, Cumberland - -	3022
Penmaen Maur, Caernarvonshire	1540	Snea Fell, Isle of Man - -	2004
Pennigent Hill, Yorkshire -	2270	Snowdon, Caernarvonshire -	3571
Pillar, Cumberland - -	2893	Stow Hill, Herefordshire -	1417
Plynlimmon Mountain, Cardiganshire - - - - -	2463	Stow on the Wold, Glocestershire	883
Radnor Forest, Radnorshire -	2163	Tregarron Down, Cardiganshire	1747
Rivel Mountain, Caernarvonshire	1866	Wendover Down, Buckinghamshire	905
Rivington Hill, Lancashire -	1545	Whernside (in Ingleton Fells,) Yorkshire - - -	2384
Rodney's Pillar (Base of,) Montgomery - - - - -	1199	Whernside (in Kettlewell Dale,) Yorkshire - - -	2263
Roseberry Topping, Yorkshire	1022	White Horse Hill, Berkshire -	893
Rumbles Moor, Yorkshire -	1308	Wrekin, Shropshire - -	1320
Saddleback, Cumberland -	2787		

Mountains in Scotland.

Of the height of the mountains in North Britain, I believe there have not hitherto been any very accurate admeasurements taken. The following are some of the most considerable, with the heights as given by different writers.

Arthur's Seat, Edinburgh -	810	Schehallien - -	3281 or 3564
Salisbury Craigs - - -	550	The most southern of the Paps of Jura - - - -	2359
Hartfell, Dumfries-shire (supposed by Mr. Jameson the highest in the south of Scotland)	3304 or 2800	Mount Battock, Kincardineshire	3450
Goatfield, Island of Arran -	2945	Cairngorum - - -	4050
Benlomond, Stirlingshire -	3262	Ben-Nevis, Invernesshire (the highest mountain in Great Britain) - - - -	4380
Benlawers, Perthshire - -	4051		
Ben Mere, Perthshire - -	3870		

Highest Mountains in the Pennine Alps.

Mont Blanc - - -	15,534	Aiguille d'Argentière -	13,379
Mont Cervin, or the Matterhorn	15,105	The Buet - - - -	10,113
Mont Rosa - - -	15,410	Dent du Midi - - -	10,500
Aiguille de Geant - -	13,984		

Highest Mountains in the Swiss Alps.

The Finster Aarhoon - -	14,307	The Eiger - - -	12,520
The Joung-Frau - -	13,185	The Monch Eiger - -	12,906
The Schreckhorn - -	12,872	The Wetterhorn - -	12,130

N. B. All these mountains are seen from the church-yard at Berne.

Highest Mountains in other Parts of Europe.

Northern Pyrenees - -	11,160	Mont Mezin, the Cevennes in France - - - -	6700
Mont Perdu, Ditto - -	10,950	Mont D'Or, Ditto - -	6189
Vigne Male, Ditto - -	10,945	Cantal, Ditto - - -	6150
Le Cylindre, Ditto - -	10,880	Puy de Dôme, Ditto - -	4750
Ætna, Sicily - - -	10,590	Vesuvius, Naples - -	3900
Le Gran Sasso, in the Appenines	8455	Mount Athos in Greece -	6780
Mont Velino, Ditto - -	7860		
Loucyra, in Dauphiny -	13,548		

Very few mountains in Europe, north of the Alps, exceed the height of 6000 feet. Some of the mountains in the chain that separates Norway from Sweden, rather exceed that height.

Lowest Line of Eternal Snow.

	Feet.		Feet.
At the Equator - - -	15,720	In Switzerland - - -	8000
Latitude 20° - - -	15,000	Latitude 65° - - -	4800
——— 45° - - -	8200		

Passages of the Alps which lead from Germany, Switzerland, and France, into Italy.

Passage of Mont Cervin (practicable only on foot) - -	11,200	The Little St. Bernard - -	7200
Of the Furka - - -	8300	Of St. Gothard - - -	6780
The Grand St. Bernard - -	8150	Of Mont Cenis - - -	6750
The Col de Ferret - -	7600	Of the Simplon - - -	6610
		The Col de Tende - -	5680

Mountains of Asia.

The Himmaleh Mountains rise from - -	20,000 to 25,600	Lebanon - - - -	9500
Ellbrus, in the chain of the Caucasus - - - -	18,500	Mount Sinai, from -	5000 to 6000

In the *Indian Ocean* there are several islands that rise from 10,000 to 13,000 feet.

Mountains of Africa.

The geography of Africa is too little known to afford any correct account of its mountains: those of Abyssinia have been estimated to be equal in height to the Alps, and the chain of Mount Atlas to equal the Pyrenees.

The Peak of Teneriffe - - 12,236 feet.

South America.

Chimborazo, Quito - -	22,700	Antisana, Peru - - -	20,680
Cotopaxi - - - -	20,320	Pic D'Orizaba, Mexico -	17,368

*North America.**

Some very lofty mountains rise on the western coast; but few of the mountains in the Apalachian chain, or the Alleghany on the eastern side, rise three thousand feet above the level of the sea.

Highest habitable Parts of the Globe.

The Farm of Antisana, Peru	13,200	City of Mexico - - -	7400
City of Micuipamha - -	11,850	Hospice of St. Gothard in the Swiss Alps - - - -	6790
City of Quito - - -	9520		

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* Long's Peak, Rocky Mountains	13,500	Saddle Back, Massachusetts -	4000
Mount Washington, the highest of the White Mountains of New Hampshire - - -	6634	Table Mountain, South Carolina	4000
Moosehillock, Ditto - -	4636	Peaks of Otter, Virginia -	3955
Mansfield Mountain, Vermont	4279	Catskill Mountain, Round Top, New York - - -	3804
Camel's Rump, Ditto - -	4188	Grand Monadnock, New Hampshire	3254

Am. Ed.

Passages in the Pyrenees.

	Feet.		Feet.
Port D'Oo	9850	Port de Carvarnie	7650
Port Viel d'Estambé	8400	Passage de Tourmalet	7130
Port de Pinède	8200		

Passages in Switzerland.

The Wengen Alp	6750	The Sheideck to Meyringen	6500

◆

MEMORANDUM.

Mr. Bakewell having been informed, by the American editor, that an edition of this work was about being published in this country, was requested to forward a notice of any alterations which he might desire to have made. A number of corrections and additions, contained in a letter dated August 30, have been inserted in their proper places, but most of those contained in another letter of the 28th October, having arrived too late, are now mentioned in the author's own language.—*Yale College*, *Jan.* 1, 1829.

"Some of the secondary strata have received names in England from the town or village where they were first examined. Such names had better be omitted or explained in a tabular view of them in a work which is to circulate in *other countries*. In the tabular arrangement p. 175 at fig. 4.

4. Oolite with subordinate beds of Clay and Sand.

a Lower Oolite - - - - - - -
A thick bed of dark Clay called Oxford or Clunch Clay - - - - - - - -
b Middle Oolite - - - - - - -
Clay with much carbonaceous matter, called Kimmeridge and Oaktree Clay - - -
c Upper Oolite - - - - - - - } *Calcaire Oolitique, &c.*

5. Sand, Sandstone, and Clay.

a Sandstone and sand chiefly siliceous called Hasting's Sand and sometimes Iron Sand } *Gres ferrugineux.*

b Clay with fresh water shells, called Weald Clay.

c Green Sand,* Sandstone } *Gres vert* and *Glauconie crayeuse of Brongniart.*

6. Chalk, &c. (as before.)

---

* Where the Green Sand and Sandstone form thick beds, in the south eastern counties of England, this formation is divided by a bed of dark blue clay into what is

Page 203, line eleven from bottom, read, Beds of dark limestone called the Purbeck beds lie over the upper oolite and are by some geologists classed with it; but they, &c.

Page 208, last line after 'fresh water shells,' read, But these beds may be regarded as a local formation, their extent being very limited.

Page 214, fifth line from top, read, Below the green sand in the south eastern counties of England, there is a considerable bed of lead coloured clay called Galt, under which there is a ferruginous sand passing in the lower part into green sand, this is sometimes called the lower green sand, and sometimes the Shanklin sand, from Shanklin in the Isle of Wight, where it occurs in cliffs on the shore. This bed of clay and the ferruginous sand under it have frequently been mistaken for the Weald Clay and the Hastings or Iron Sand, and there is at this time a considerable difference of opinion among English geologists respecting the identity of these strata in various situations. In formations necessarily so variable as the beds of sand, sandstone, clay and marle that intervene between the chalk and the oolite, the identification of the strata in different situations seems an object of trifling importance in itself. But as it is now discovered that the strata between the upper oolite and the lower green sand whereon they occur, contain the remains of fresh water animals and land plants, (probably intermixed with some marine shells,) these strata and those above and below them become entitled to the careful attention of the geologist who is desirous to trace the changes that have taken place in the condition of our planet, as indicated by the remains of its ancient inhabitants.

Page 251, line seventh from bottom after smoke, add the following note.

It has been denied that smoke is ever emitted from volcanos, but as bitumen abounds in the products of ancient volcanos in Auvergne, and occurs in the lava of several recent volcanos, smoke must have been emitted during the eruption of such lava."

---

now generally called upper and lower Green Sand, the latter is often ferruginous and has frequently been confounded with the Hasting's Sand or Iron Sand and the blue clay called *Galt* has been mistaken for the clay called Weald Clay. The latter appears to become thin or to be entirely wanting in many parts of England, where it might have been supposed to occur.

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OUTLINE

OF THE

COURSE OF GEOLOGICAL LECTURES,

GIVEN IN

YALE COLLEGE.

NEW HAVEN:
PRINTED AND PUBLISHED BY HEZEKIAH HOWE.
1829.

DISTRICT OF CONNECTICUT, ss.

L. S.

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PREFACE.

This outline of my course of geological lectures, is to be regarded, as a skeleton, furnished indeed with some of the principle muscles; but, destitute of the color and finish, of a perfect form. To my pupils, to whom it has particular reference, it may serve both as a guide and a review, and should it prove, in any degree, useful to others, I shall be gratified. It is intended as an outline of the *philosophy of geology;* according to the best views, which I have been able to take of the subject. Those who may peruse it, will, however, do me the justice to believe, that in the progress of the lectures, full details are given, and numerous specimens of rocks exhibited, both Foreign and American, in the order proposed, with ample descriptions of their mechanical and chemical constitution—their organized remains, and the order of their arrangement and connexion, and some subjects are discussed which are not even mentioned in this general sketch. As it is the *fashion* of the day, to attribute almost every thing in the earth to igneous agency, I shall probably be thought to be behind the present state of opinion, while I maintain, that the chemical affinities, through the medium of aqueous solutions of the great chemical agents—as well as of water itself, have also produced important effects in the early arrangements of the planet.

If Werner attributed too much to these causes, may there not be danger, at this day, of vibrating to the opposite extreme? It is indeed already proved, that igneous agency has been vastly more extensive than was formerly believed, and it is probable that evidence of this kind will accumulate, as the researches of well instructed geologists are directed, more and more, to this important topic. But, why exclude any of the great powers, which we find in actual operation; or, of whose ancient activity there appears probable evidence?

In the absence of positive evidence, it is perfectly justifiable to reason, analogically, upon facts and principles, well ascertained by experiment and observation; always bearing in mind, however, that there are probably many agents and agencies, of which we are still ignorant, and that the discovery of some new power, or of some new mode of operation in those already known, might, very materially alter, nay, perhaps entirely subvert conclusions, in which we have been accustomed to repose unlimited confidence. Such a train of thought is far from being agreeable, for we are always prone to reason, on every subject, as if we understood the whole matter; but, the history of science has abundantly proved that philosophy, after building splendid systems, has, in consequence of its own discoveries, been often obliged to return to the humble task of learning its elements anew.

The arrangement implied in the following sketch is, it will be perceived, founded upon the great outlines of the Wernerian plan. Whatever may be the errors and imperfections of that system, (for it undoubtedly has both,) its great outlines still appear to be founded in truth, and to present the best clew to conduct the young pupil through the labyrinths of geology. It has become fashionable to decry Werner; but, without being his blind admirer, I may be permitted to ask, who has done more for geology, and who has done it better?

The author of this sketch begs leave to add, that, desirous of following truth only, he has kept himself disentangled from the prevailing geological systems; and, although trained in geology principally at Edinburgh, in the schools both of *fire* and *water*,[*] he is neither Wernerian nor Huttonian, Neptunian nor Plutonist; but simply a student of facts—a learner, from those who certainly know more, and a teacher to those who may possibly know less. Being habitually occupied, as a part of his public duties, in presenting to his pupils, the great *facts* of geology, and in reasoning upon them; he accepts, with equal readiness, the agency of fire or water, or other agents, as they may appear best adapted to explain a given effect, and he has no hesitation in calling in the aid of all the great natural powers, whether mechanical or chemical, as there may be occasion.

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[*] Hope, Playfair, Murray, Hall, Jameson, Seymour, &c. were the active men of that place, and period, (1805–6,) and several of them were then, and some are still, public instructors, or distinguished writers in geology.

So far as the following arrangement is founded upon the Wernerian plan, it is one of convenience merely, and therefore there is no hesitation in deviating from it, or in substituting other views, when they appear preferable.

Had Werner lived till this time, he wôuld probably have admitted that the differences between the trap rocks and the lavas have become evanescent, and that it is certainly possible, if not probable, that they may have had a similar origin.

On the other hand, those authors who banish the transition class of rocks, being still obliged to describe such rocks, (because they exist, and cannot be annihilated by the stroke of the pen, which erases them from an artificial system) are compelled to divide them between the primitive and secondary rocks, which produces confusion and inconvenience, and destroys the distinctness, which, to a great degree, marks the three great divisions of primitive, transition and secondary. The rocks of North America, as far as they have been examined, correspond, in general, remarkably well with the great outlines of Werner; and who in North America has done so much to develop the grand features of our geology, as the AMERICAN WERNER, WILLIAM MACLURE, whose industry and acumen are equalled only by his candor and freedom from the bias of system.

The views presented in this sketch have not been adopted, without full consideration of the facts upon which they are founded.

The study of those facts seems necessarily to conduct us to the conclusion, that the proofs of both succession and revolution, connected with time, and with both order and disorder, which are so abundant and decisive in the crust of our planet, cannot all be referred to the deluge. That great convulsion is indeed recorded on the surface of the earth in indelible characters, and it is impossible to weigh the evidence which geology presents in support of it, without admitting, independently of history or tradition, that it has happened. The facts that must be referred to it, are numerous, and highly important and interesting.

But it is impossible, upon any sound principles of philosophical reasoning, to refer to the same event—a still more extensive, various and interesting class of facts, relating chiefly to the rocks composed of ruins and fragments, and to those containing organized remains, in a mineralized and consolidated state, entombed in the solid strata and mountains. This is a vast field of observation and instruction, and it is less known even to the greater number of intelligent and educated persons, than almost any department of knowledge. None but geologists study it with diligence, and none who have not made themselves masters of the facts, are qualified to judge of their importance and of their bearing. The subject *requires*, for full illustration, the exhibition of a great many facts, either in the fields, mines and mountains, or, as an imperfect substitute, in the cabinet. Persons who are entirely destitute of this species of information, can never have formed the habit of comparing one fact in geology with another, and of thus estimating their relation to each other, and to the entire planet. It is very difficult to find access, on this subject, to many minds, otherwise enlightened, and habituated to receive and weigh evidence with candor and intelligence. The reason obviously is, that they are not in possession of the first elementary conceptions of the subject; if the facts are not denied, they are neglected, and fail to make the impression on the mind which they must always produce, when fully understood and realized. No well instructed geologist hesitates to refer them to an earlier period than the deluge, and to a widely different order of things.

This distinction, it will be seen, pervades the following sketch, and the writer believes that no consistent and rational account of the structure of the earth can be given upon any other plan.

* * * * * *

Are the discoveries of geology consistent with the history contained in the book of Genesis?

Respecting the deluge, there can be but one opinion, and that opinion has been already stated; geology fully confirms the scripture history of that event.

There is doubtless more difficulty as to the earlier periods; but the writer, after studying the subject for many years, has formed the opinion, that the geological facts are not only consistent with sacred history, but that their tendency is to illustrate and confirm it.

It is true, that the Bible is not a book of physical science, and that its allusions to physical subjects are, in the main, adapted to common apprehensions. Still, there are two great events recorded in it, which, although they have a momentous moral bearing, are, *in their nature*, entirely physical; we allude to the creation and arrangement of the planet, and to the deluge which was made to sweep over its surface. Why should any one refuse to attend to a history of these two stupendous events, merely because that history professes to have proceeded from the same author as the work itself; and why should we suppose that the brief notices of the great *physical* facts, connected with a *physical creation* and a *physical destruction*, are not correctly stated, in this earliest and most venerable of histories?

If all our discoveries regarding the surface and the interior of the planet tend, when properly understood, to confirm the credibility of both these events, and to enable us to discriminate between the circumstances and evidence which belong to them respectively—what moral consideration can, in this case, forbid a happy application of the discoveries of science, and why should science refuse to lend its aid to the support of moral truth!

YALE COLLEGE, January 12, 1829.

REMARK.

The succeeding sketch is not intended to contain minute descriptions of rocks, but is occupied, principally, with their general characters—their probable origin as regards the immediate physical agents, and the order of time in which they were deposited.

INTRODUCTORY VIEWS.

GENERAL OBJECT OF GEOLOGY.

The object of this science is to ascertain as far as possible, the structure of the earth; the nature of the mineral aggregates which it contains; the disposition, or arrangement of these aggregates, forming the great masses called rocks; the relative position and nature, of the rocks themselves; the useful substances which they contain; the common or natural associations of these with other substances; the proximate causes, which have, probably, given the mineral masses their present form and position; and those, which, operating upon them still, are causing them to undergo alterations, more or less considerable, and are even, in some instances, producing changes, which will ultimately give them new forms of existence.

POSITIVE AND SPECULATIVE GEOLOGY.

It is obvious, therefore, that geology is erected upon facts, and not upon mere speculation; yet, speculation is with propriety admitted, as a part of the means of advancing the science; in some cases it is an important part, but it is of no value if not founded upon facts, and facts must never be contradicted by it.

Positive geology is incomparably more important than speculative, and it proceeds, like the other natural sciences, upon a careful examination of particulars. From particulars, it ascends to generals, and upon these, builds legitimate conclusions. Thus, there is a clear distinction between geological theory and geological hypothesis. The former draws conclusions directly from facts, and follows strictly the inductive course. It has therefore the same foundation, as general physics; and its conclusions often approximate to demonstration. The latter also appeals to facts, but, in a manner less conclusive and it makes suppositions of facts, not actually proved to exist. For instance: when we observe, that vast quantities of aerial agents, especially of steam, are ejected from volcanos, we reason conclusively, that these agents are employed to raise the lava, and that they cause it to flow over the crater or to burst through the side of the mountain; for, we know, from familiar facts, and experiments, that these agents have power enough to produce such an effect; we know, that in the case supposed, they are present in sufficient quantities, and we are ignorant of any other causes, that might produce these effects, or that may be believed to exist in these circumstances. But, when we enquire for the causes of the heat that produces the steam, and evolves the other aerial agents, we are obliged to speculate. We may say, perhaps, that the voltaic or galvanic powers are the principal agents, and we may even render it highly probable, nay, quite credible; but, we cannot prove the fact, and therefore, our solution rests as an hypothesis; but, of that class of hypotheses which, being built upon analogous facts, approximate to legitimate theory.

If we reason concerning the cause of the magnetism of the earth, we may suppose, that there is a great mass of magnetic iron within the planet; but, this is an hypothesis of a lower order than the one just named; because, we have no analogies to support our conclusion, except that iron can become magnetic and that the mean specific gravity of the earth is about 5., water being 1.; and we invent the cause, on purpose to account for the effect.*

Positive geology is every day augmenting its already rich stores of facts; and speculative geology is building its conclusions upon a basis, which time is rendering more and more solid.

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* The beautiful fossil fish found in marly lime stone, in Mount Bolca, inform us that they were living and active beings, just before those hills were deposited, and when the waters stood over the place where they now are; this is a pregnant truth—but, if we say, with some, that they were overwhelmed by a volcanic eruption, we speculate, some would think plausibly, others fancifully.

LIMITS OF OUR KNOWLEDGE OF THE EARTH.

It is only the *crust* of our earth that we can examine; a few thousand feet, or, at the utmost, a few miles of its outer rind. We no longer attempt, by a brilliant excursion of the imagination, to account for its present form; poetry and fiction have ceased to perform the work of philosophy; those obsolete theories, or rather hypotheses—many of them adorned by the eloquence of powerful minds—which substituted waking dreams for the patient examination of facts, are no longer regarded, except as monuments of the restless activity of the human mind; which is inclined to repose on almost any hypothesis, however visionary, rather than to confess its weakness and ignorance. Buffon could believe, that the earth was struck off from the sun, by the tail of a comet, while it remains to be proved, that a comet has any palpable matter, where we observe that peculiar effulgence; or even if there is, that the firm globe of the sun, would receive injury from such a collision; any more than a cannon ball would be broken, by the stroke of an iron rod.*

A great number of highly qualified men are now occupied in geological researches; they bring to the investigation, all requisite science—the habit of careful induction, and the industry and patience, which are demanded; and the progress made in these enquiries, since the commencement of this century, is wonderful. Districts, provinces, countries and even continents are, more or less, extensively surveyed; and this kind of research, favored by the propensity for travelling, to which it affords both a high incitement and constant gratification, will, doubtless, continue to be extended, until there shall be no countries unexplored, except those from which the *scientific* traveller is debarred, by insuperable moral or physical impediments.

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* The geological student may find a spirited outline of the most prominent geological hypotheses in Cuvier's Introduction to Geology; they may be read as a matter of amusement; but it will be easily perceived, that they bear no closer analogy to modern geology, than the visions of Alchemy sustain to modern chemistry.

Geology is, therefore, now entitled to a rank among the physical sciences, and is entirely worthy of the attention of the greatest minds.

In grandeur, it falls indeed short of astronomy; and what physical science does not; since, astronomy presents to our optics, or to our intellectual vision, the "great frame work" of the universe; we pass from the view of our own planet to the entire planetary system, of which our earth is a member; and from this system, to other and similar systems; and to the immense system of systems—of suns innumerable, with their attendant worlds, arranged and connected, in perfect harmony; performing all their revolutions without interference, or irregularity, and illustrating the power and wisdom and sustaining energy, of the omnipotent Creator and Governor. Still, the structure of a single planet is a subject of great interest and of no small grandeur; especially as we may reason from it *analogically*, although not indeed conclusively, respecting the structure of other planets.*

MODES OF INVESTIGATION AND SOURCES OF OUR KNOWLEDGE.

Our direct penetration into the earth, by mines, the deepest excavations of art, has scarcely exceeded three thousand feet or a little more than half a mile, not $\frac{1}{8000}$ part of the earth's diameter or $\frac{1}{4000}$ part of its radius.

It might therefore, at first view seem that we can attain only a very slight knowledge of the internal structure of the planet, and that it would be idle to attempt to reason respecting that of which we can see so little. Still, we are not without probable grounds of reasoning correctly upon this subject, for we have various sources of information and means of perusing the internal disposition of our globe; the most important are derived, from

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* The only positive knowledge which we possess on this subject is derived from the meteoric stones whose foreign origin cannot be reasonably doubted.

The observations made by telescopes, upon the moon, have discovered a surface similar to that of our earth, but vastly more mountainous and as it is now thought highly volcanic. See our author, Appendix, p. 386.

1. *The obliquity of the strata.*

The strata or natural beds of rocks are found in all positions, from the perfectly vertical, to the perfectly horizontal. Were they all horizontal, it is obvious, that the edges could come into view, only on the sides of mountains, in the banks of rivers, in promontories, &c. and in artificial excavations; and that, in a tolerably level country, we might travel over many leagues, and see very little change in the rock formations.

But if, as happens in most countries, the strata are inclined to the horizon, then, their edges must of course, come into view, provided their obliquity does not change, and provided the rocks are not concealed by their own ruins, or by the general soil. Thus strata, that in a given situation are many miles below the surface, may, and necessarily, must, (under the limitations above specified) come into view, and *crop out*, as it is technically termed, in some place or another. Could we suppose, that for many leagues of surface, measured on a right line, the soil and diluvium were completely removed, from a series of rocks, inclined to the horizon, then, their edges would come fully into view, and we could have no reasonable doubt that we should see an adequate representation of the subterranean geography, as far as those strata extended; and probably for many leagues—it might be even for hundreds of miles beneath the surface. The same remark will of course apply to the strata that are vertical, and indeed to those in all positions, except the perfectly flat; and even then, we are not without means of studying them in the modes already suggested, or, which will be immediately indicated.

2. *Horizontal position of the strata.*

Strictly, this is a position parallel to the general curve of the earth's surface, considered without reference to its superficial inequalities; those inequalities themselves, that is the hills and mountains being supposed to have a similar structure. In that case, it is certain, that were this position strictly preserved and were there no perforations and ruptures of the strata, by artificial or natural causes, we should, except in the sides of hills and mountains, see only the upper stratum of rock, and our knowledge of the geology of the region in question, would be confined, very nearly, to the visible material beneath our feet.

We are not informed as to the figure of the nucleus of the earth, but, if it be irregular or even not globular, the strata deposited upon its different sides, or surfaces, may exhibit every degree and variety of obliquity; and the stratum, which, in a given situation, appears horizontal, may in fact, copy, not the great curve of the earth, but a plane, which if continued, would take off a segment of the globe, and thus the edges of the strata would, at their exit from the ground, come distinctly into view, although the surface of the country should be horizontal.

It is impossible to say whether the earth has a solid nucleus or not. If it has, and this nucleus is any thing but a sphere or a spheroidal figure, then the various faces which it would present, might cause the superposited strata to assume every position from flat to vertical, and there would be no occasion to admit that strata, originally arranged in one position, had been by force, elevated into another.

If we admit a nucleus having plane faces, or faces not spheroidal, and allow that the crust of the globe has been accumulated around the nucleus, then it would be possible, that planes of stratification might extend through a large portion of the planet, and might even jut out on opposite sides. If this suggestion were well founded, then the view of the crust might present a fair specimen of the interior, or at least to a considerable extent. The nucleus would however, by the supposition, be covered by the superimposed masses, which might, or might not correspond with it in their nature.

If there be no mistake in the conclusions of the British and French philosophers as to the high mean specific gravity of the earth, the planet is, on an average, at least twice as heavy as the most common rocks and stones with which we are acquainted.

Does this discovery imply a prevalence of metals in the interior of the earth? Is the nucleus iron, or at least is iron diffused in great abundance in the interior of the earth, and does this account for the magnetism of the globe, although the magnetism of iron itself is still to be accounted for? Or does some other metal or do some other metals, of considerable specific gravity, prevail in the constitution of the earth? If there were known to be a nucleus of silver, gold or platina, there would soon be found adventurers hardy enough to attempt even the centre.

Where we are deficient in positive knowledge, we are at liberty to make suppositions, provided they are consistent with the known constitution of things.

It is then clearly possible, that matter, of the same kind as that which forms the rocky strata, on the surface, may exist below, in a degree of condensation, sufficient to account for the high specific gravity of the earth. We are not without examples in natural substances.

Carbon, in diamond, is three or four times as heavy as in the bitumens, and six or eight times as heavy as in charcoal; alumine in sapphire sustains a similar relation to the alumine of clays, and so does magnesia in the state of pulverulent native carbonat, or mountain cork, to magnesia in the boracite, or in the chrysolite, and silex in swimming flint, (quartz nectique) and in rock crystal, are in a similar situation.

It is possible, therefore, that the very minerals which we see on the surface, may, in the interior of the earth, have a double specific gravity.

It is a splendid conception, built upon the discoveries of Sir H. Davy and Prof. Berzelius, that the metals of the earths, and not merely the earths themselves may exist in the interior, and thus the nucleus of the planet may be principally a mass of metals, as its crust certainly is of metallic oxids.

All these views tend to shew, that it is possible, to reconcile the apparently contradictory specific gravity of the surface and of the entire mass of the earth; and, were this the proper occasion, it might be easily proved, that these views are very interesting to general physics, and particularly to geology, in enabling us to understand the phenomena of earthquakes and volcanos.

But, for want of positive information as to the state of facts, it is impossible to reason conclusively on this subject, and the recent researches of Cordier tending to prove the existence of a state of igneous fusion in the interior of the earth and at no very profound depth, must, if confirmed, very materially influence our opinions. But philosophers will be slow to admit such appalling conclusions from the premises hitherto presented.

3. *Mines.*

The excavations made in mining are the greatest with which we are acquainted. The deepest mine in the world, that of Truttenberg in Bohemia, penetrates three thousand feet into the earth. In all mines, the strata are, of course, more or less perforated and broken, so that we obtain the most satisfactory information— as to the nature of the rocks and their disposition. Few of the mines of England are in perpendicular descent, deeper than twelve hundred feet (Dolgoath in Cornwall) and none in the United States exceed three or four hundred, (Richmond coal mines.)

4. *Wells.*

The evidence afforded by wells is of the same nature. The depth attained rarely equals one hundred feet, but in some instances it extends to two hundred, three hundred, four hundred, &c. as at Carisbrooke castle in the isle of Wight, on the plain or valley of London, &c. (Conybeare and Philips.)

5. *Boring for saltwater, salt mines, coal, &c.*

This is an operation of the same kind, and affords, as regards the rocks, similar evidence, although less distinct; because the materials are brought up, in the state of powder, or at least of fragments, and a very imperfect idea is thus obtained of their original appearance; sufficient however to enable us to decide on their nature. These operations are often carried on to the depth of several hundred feet.

6. *Roads, canals,[*] tunnels.*

The two first rarely penetrate to any great depth, but sometimes there are deep cuts through diluvium, and even through solid rocks. The former is seen, very strikingly, on the Welland Canal, in Upper Canada; the cut through the diluvium being, in some places, more than fifty feet, in a stiff tenaceous clay, and the latter circumstance is particularly remarkable at Lockport on the Erie Canal, where for two miles or more, a very solid, subcrystaline limestone has been excavated by blasting in many places to the depth of thirty feet, disclosing not only the nature of the rock, but many beautiful imbedded minerals.

Tunnels are not numerous. Every one has heard of those of the Duke of Bridgewater, on the Canal leading from Liverpool to Manchester,[†] and of that now making under the Thames to serve as a substitute for a bridge.

It appears that they were not unknown to the ancients. From the Stadium near Athens, situated in a natural defile, the vanquished charioteers retired through a tunnel which perforated a neighboring hill, and thus those who had failed of victory were screened from the sneers and insults of the populace.[‡] These and all other excavations into the earth add to our means of geological information.

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[*] The French, during their celebrated expedition to Egypt, under Bonaparte, traced and described the ancient and magnificent canal connecting the Mediterranean and the Red Sea, but which from the ignorance of locks in ancient times could be navigated only when the waters were high, and was therefore nearly useless.

[†] That stupendous work of art, the canal tunnel, under Standedge, between Huddersfield and Manchester, extends under ground upward of three miles, and is two hundred and twenty yards below the surface. The length of the voyage through the tunnel and back again is six miles and a half.—*English Newspaper.*

[‡] Dr. Howe's personal communications, Aug. 11, 1828.

7. *Rivers and other water courses.*

From the humblest brook, that transports the gravel and sand along its current, to those stupendous rivers which force their way through mountain defiles, and appear as if they had burst the barriers that were once opposed to them, we derive geological instruction. The ruins which, in the form of sand and gravel and pebbles and sometimes even bowlder stones, they bear along in their course, or vex with incessant friction, till their angles are rounded or obliterated, afford us valuable information; and the sections of banks of gravel or of rocky strata which the waters expose, impart to us hints which we may turn to great account.

In many places, the rivers appear to have formerly flowed at a higher level, than at present, or to be the remnants of lakes whose barriers time has levelled or broken; and it is no uncommon circumstance to find water-worn ledges of rocks at elevations higher than any place where waters can flow at the present time. This is undeniably the fact in the vicinity of Bellows falls on Connecticut River, especially two or three miles below the falls, on the eastern side; here the primitive rocks shew the same water-rounded angles, furrowed lines and even pot holes, evidently, formed and polished by incessant friction, as are exhibited at the falls themselves, where these operations are now incessantly going forward. Similar facts are observable in the transition limestone near the head of lake George, at a considerable elevation above the lake, in ledges over which no water now flows but that of the atmosphere; "the angles are rounded and smoothed and there are numerous holes worn into the solid rock, sometimes shallow and irregular, but frequently deep and cylindrical, and bearing a very exact resemblance to those which are common in the ledges, upon which cataracts fall, and appearing to have been produced by the same cause, namely, the wearing agency of water, aided by small stones which it impels in incessant whirling revolutions."*

The passage of the Shenandoah through the blue ridge—of the Connecticut just below Middletown, through the Haddam hills, and of the river described by Lewis and Clark through the Rocky mountains, are a few among innumerable examples of this kind. It is very immaterial for geological purposes, whether the rivers have burst their barriers, or merely uncovered the rocks so that their characters can be observed; for, in either case they contribute to the mass of geological evidence.*

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* American Journal, Vol. IV. p. 44.

8. *Valleys and defiles.*

These are often deep cut and abrupt and of great extent, exposing the stratification on the sides of hills and mountains. The structure must in this manner, be more or less revealed, in every mountainous country, except so far as the sides are covered with soil and ruins. As a large part of the earth is mountainous, provision is thus made on a great scale for judging of the interior of the planet.

9. *Precipices, cliffs, promontories and abrupt banks.*

The shores of the seas and of the great lakes abound with such exhibitions, and all countries except those that are very low present them in great frequency. Many of them are inaccessible except in boats from the water side, but however viewed, they exhibit the stratification and structure more or less distinctly.

10. *Landslips, Slides and Avulsions.*

The peaceful dweller in the beautiful Isle of Wight, in the English channel, not unfrequently, sees the high chalky cliffs of that coast, that have been undermined by the sea, totter to their fall, till they come thundering down ; and even at some distance from the sea, they occasionally slide or slip from their foundations, covering the plains below with ruins.

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* Although it cannot be supposed that rivers have generally formed their own beds, there can be no doubt that these currents of water do often increase the depth and alter the form of their channels. The Genessee River and the Niagara River afford fine examples of the exhibition of stratification of river banks, by the wearing effects of water. The banks of these two rivers are often precipitous and of several hundred feet in elevation, giving very perfect sections of the strata.

The mountaineers of the Alps witness still more stupendous catastrophes. Large mountain masses, and even considerable portions of mountains, fall into the valleys and plains, and choke them up, or fill the bosom of lakes, spreading desolation through villages—burying their inhabitants in the wreck, or sweeping them away by the overflowing of the waters.

Even the Green Mountains of Vermont, and the White Mountains of New Hampshire, have been the scenes of similar catastrophes, and the Notch in the White Mountains, will long record the desolations of July, 1826.*

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* The slides in the White Mountains of New Hampshire, and the Green Mountains of Vermont, have been recently very remarkable. (See Am. Journal, Vol. XV. Art. II.) There is a grand defile or pass in the White Mountains, called the Notch. The portion which is the grandest, is about five or six miles in length ; it is composed of a double barrier of mountains, rising very abruptly from both sides of the wild roaring river Saco, which frequently washes the feet of both barriers; and sometimes there is not room for a single carriage to pass between the stream and the mountains; but the road is cut into the mountain itself. This double barrier, rises on each side, to the height of nearly half a mile in perpendicular altitude, often exceeding this height; and it is capped, here and there, by castellated turrets of rocks, standing high above the continued ridges; these are not straight, but are formed into numerous zigzag turns, which frequently cut off the view, and seem to imprison the observer in a vast, gloomy gulf.

The sides of these mountains are deeply furrowed and scarred, by the tremendous effects of the memorable deluge of August 28th, 1826, which, on the night succeeding that day, destroyed, in a moment, the Willey family, nine in number, and left not one to tell their story. They occupied a lonely house in the wildest part of the Notch, at the foot of the mountains; it was a resting place for travellers. For two seasons before, the mountains had been very dry, and on the morning of Aug. 28th, it commenced raining very hard, with strong tempestuous wind; the storm lasted through that day and the succeeding night, and when it ceased, the road was found obstructed by innumerable avalanches of mountain ruins, which rendered it impossible to pass, except on foot. The first person who came to the Willey house, found it empty of its inhabitants, and in the course of a few days the mangled bodies of seven out of nine, were discovered a short distance below, buried beneath the drift wood and mountain ruins, on the bank of the Saco, or rather in the midst of what was for the time, a vast raging torrent, uniting one mountain barrier to the

It is obvious therefore, that our means of perusing the structure of the interior of the earth are not so scanty, or so imperfect, as might at first view appear.

This at least may be said with truth, that, although we cannot prove what is the constitution of the earth one thousand, or even one hundred miles from its surface, we have means in our power of deciding upon the nature of the crust. Whether in one quarter of the world or in another, we ascend the loftiest mountains, and examine the awful peaks on which the sunbeams shine, first and last, as the sun rises and sets, and on which the storms of ages have spent their fury; or whether we descend into the deepest mines, and observe the strata uncovered, for the first time, since their formation; in whatever country; under whatever circumstances, we examine the earth, we are led to the important con-

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other. The effects of the torrents, which on that occasion descended from the mountains, now form a most conspicuous and interesting feature in the scenery.

The avalanches were very numerous; they were not, however, ruptures of the main foundation rock of the mountain, but *slides*, from very steep declivities; beginning, in many instances, at the very mountain top, and carrying down, in one promiscuous and frightful ruin, shrubs and forests, and the earth which sustained them; stones and rocks innumerable, and many of great size, such as would fill, each, a common apartment: the slide took every thing with it, down to the solid mountain rock, and being produced by torrents of water, which appear to have *burst*, like water spouts upon the mountains, after they had been thoroughly soaked with heavy rains, thus loosening all the materials that were not solid, and the trees pushed and wrung by fierce winds, acted as so many levers, and prepared every thing for the awful catastrophe. No tradition existed of any slide in former times, and such as are now discovered to have anciently happened, had been completely veiled by forest growth and shrubs. At length, on the 28th of June, two months before the painful event, there was an avalanche, not far from the Willey house, which so far alarmed the family, that they erected an encampment a little distance from their dwelling, intending it as a place of refuge. On the fatal night, it was impenetrably dark, and frightfully tempestuous; the solitary family had retired to rest, in their humble dwelling, six miles from the nearest human creature. The avalanches descended in every part of the gulf, for a distance of two miles; and a very heavy one began on the mountain top, immediately above the house, and took its course in a direct line towards it; the sweeping torrent, a river from the clouds, and a river full of earth, stones, trees, and rocks, rushed to the house, and marvellously divided within six feet of it, and just behind it, and passed on either side, sweeping away the stable and horses, and completely encircling the dwelling, but leaving it untouched. At clusion, that the great features are drawn upon the same plan, and that similar laws have governed the whole series of formations.

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Fruits or results of the observations made on the structure of the crust, in consequence of the use of all the means in our power.

The earth is not (as ignorant persons usually suppose) rudis indigestaque moles, *a mere rude and unarranged heap of rocks*, and minerals, grouped together without order, without plan, and without a possibility of being rationally investigated.

Order, so distinctly observed in the mechanism of the universe; in the stellary and planetary systems; in the admirable

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this time, it is supposed the family issued from their door, and were swept away by the torrent.

Had they remained, they would have been entirely safe. They probably did remain amidst the war of wind and rain and mountain torrents, and the tremendous crash of the forests—earth and rocks, which for miles around them were rushing down in one wide scene of desolation, and with an astounding noise and concussion, of which, we can form no adequate conception; until the evident and near approach of the ruin immediately behind the house, left them, apparently, no alternative, but to fly from instant death. Even now (May 29, 1828,) almost two years after the event, there is a great rampart of earth—stones—rocks and trees, piled up within five feet of the house, and behind it and making a circuit round it, as if *repelled* by an invisible power. But the little green in front, and east of the house was undisturbed, and a flock of sheep, (a part of the possessions of the family) rested on this small spot of ground and were found there the next morning in safety—although the torrent which has been mentioned as dividing just above the house, and forming a curve on both sides, had swept completely around them, and again united below, and covered the meadows and orchard with ruins, which remain there to this hour. This catastrophe presents a very striking example of sudden diluvial action, and enables one to form some feeble conception of the universal effects of the vindictive deluge which once ravaged every plain and defile, and swept over every mountain. In the present instance, there was not one avalanche only, but there were many. The most extensive single one, was on the other side of the barrier which forms the northern boundary of the Notch. It is described as having slid, in the whole, three miles—with an average breadth of a quarter of a mile; it overwhelmed a bridge, and filled a river course, turning the stream, and now presents an unparalleled mass of ruins. There are places on the declivities of the mountains in the Notch, where acres of the steep sides were swept bare of their forests, and of every moveable thing, and the naked rock is now exposed to view.

equilibrium of projection and gravitation; of cohesion and expansion; of cohesion and chemical affinity; in the beautiful structure and exact economy of animals and vegetables; and in the still more wonderful phenomena of mind, does not end there: it pervades all the other works of God; and in this rude, unconscious earth, is not less capable of proof, (although that proof is less obvious) than in the other departments of his universal dominion.

Still, while this regularity is thus manifest, and is the prevailing character, it must not be forgotten, that the earth exhibits, in every country, *decisive* proofs of violence, derangement and dislocation of strata; indicating the operation of various catastrophes. For example, in mines, strata are found, whose continuity is bro-

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In the greater number of instances however, the avalanches began almost at the mountain top, or high upon its slope. The excavation commenced, generally, as soon as there was any thing moveable—in a trench of a few yards in depth, and of a few rods in width, and descended down the mountains—widening and deepening—till it became a great chasm, like a vast irregular hollow cone, with its apex near the mountain top, and its base as its foot, and there spread out into a wide and deep mass of ruins, of transported earth, gravel stones, rocks and forest trees.—*Letter of the Editor, written on the spot, May* 20, 1828.

A party of gentlemen who assended Mount Washington, the next day after the the storm, counted thirty slides on the western side of the mountain. They began near the line where the soil and vegetation terminate, and growing wider as they decended, were estimated to contain more than a hundred acres. These were all on the western side of the mountains. They were composed of the whole surface of the earth with all its growth of woods, and its loose rocks, to the depth of fifteen, twenty, and thirty feet. And wherever the slides of the two projecting mountains met forming a vast ravine, the depth was still greater. In some places the road was excavated to the depth of fifteen and twenty feet; and in others it was covered with earth, and rocks, and trees, to as great a height. In the Notch and along the deep defile below it, for a mile and a half, to the Notch House, and as far as could be seen beyond it, no appearance of the road, except in one place for two or three rods, could be discovered. The steep sides of the mountain, first on one hand, then on the other, and then on both, had slid down into this narrow passage, and formed a continued mass from one end to the other.—*Letter of Rev. Carlos Wilcox.*

The account of the slides in the Green Mountains will be quoted in connexion with the notice of diluvial action, in the latter part of this sketch.

ken;—suddenly, at a particular depth, a certain rock, which is observed, on one side of a shaft or fissure, disappears on the other, and some different rock comes in its place; yet the first rock may be found again, either above or below the place where it disappeared, and with it all the attendant series of rocks, which in like manner were dislocated.

Again, a certain series of rocks may be cut across, by a different species of rock, which shall completely separate all the successive strata, and yet on both sides they may be found re-appearing either at the same elevation, or at a different one. The matter which fills the fissure is technically called a *dyke.*

Again, strata are sometimes found at particular places tortuous or winding, or angular; although they may, in general, be regular, thus indicating, as many suppose, the application of force to them, and their disturbance by a mechanical cause. Notwithstanding these and other similar irregularities,

A general regularity of arrangement has been observed in the structure of the globe.

The great mass of *the crust* of the earth, and probably of *its entire solidity*, is, in every country made up of rocks which have the following characteristics.

PRIMITIVE ROCKS.

I. *The most important fundamental rocks of our globe are composed, in general, of crystaline materials*, bearing every appearance of having been deposited, from a state of prevailing repose, and chiefly by the exertion of chemical affinities; they are made up principally of imperfect and confused crystals, or of parts, having more or less of a crystaline structure, adjusted to each other, either confusedly or by salient and re-entering angles, so as to form a mass of continuous matter; furnished however, sometimes with cavities, which are occasionally lined with large and beautiful crystals. Every thing in the appearance of these rocks implies a previous state of chemical mobility, (not of mechanical suspension) and the only powers with which we are acquainted, that are at all equal to the effect, are water and fire, aided by various saline, alkaline, acid, and other energetic chemical agents, which, in large quantities, we now find actually entering into the constitution of these rocks, and of other terrestrial masses, and which were therefore originally provided in the grand store-house of created materials.

Few of those who would employ fire to form the primitive, as well as the volcanic and trap rocks, go so far, as to exclude the operation of water, or of chemical agents, of which water may have been the basis and vehicle. Indeed, it is generally agreed, that, judging from the appearances of things, we must conclude, that the earth was originally, and for a long time, submerged, and that its crust at least, has been in a soft and impressible state, if not partially or wholly in solution.

Geology declares, that the original, or at least early state of the surface of the planet, was that of a watery abyss; and the book of Genesis, in the concise account which is there exhibited of the origin of things, reveals the same fact, as well as the recession of the waters, by which the dry land was made to appear.

We may therefore take it for granted, that the aqueous abyss preceded the habitable condition of the earth, and we are at liberty to reason upon its probable constitution and possible effects.

It was evidently a fluid of very different properties from mere water. It doubtless contained all the chemical agents, not only that are soluble in water, but also that are soluble in a compound fluid, consisting of water, and of other agents still more active. The acids alone would give it great solvent powers, particularly in relation to the alkalies—the metallic oxides, and several of the earths; the alkalies alone would impart a similar efficiency, especially with respect to silex, which is not readily soluble in any acid except one; acids may have prevailed at one time, and alkalies at another; and even if acids and alkalies, and acids and earths, and acids and metallic oxides, had been present at the same time, and had mutually combined, so as to form saline compounds, these compounds, as far as they remained in solution, would impart to the fluid peculiar and increased solvent powers; and those compounds which, from their insolubility, were precipitated, would be of course removed, and would not be in the way to impede other agencies. In the constitution of mineral bodies, we find the greater part of the most active chemical agents; the powerful acids, the sulphuric, the muriatic, the nitric, the phosphoric and the fluoric; and the carbonic, although not powerful, is abundant. The alkali soda exists in vast abundance, and often combined with no other acid than the carbonic; while potassa, as well as soda, is found in combination with other principles in a great many minerals, and lithia in several. The alkalies are largely, and the alkaline earths are considerably soluble in water; all the earths are easily soluble in acids, except silex, and even this is powerfully attacked by fluoric acid, and, under certain circumstances, is not unaffected by some other acids. All the metallic oxides are soluble, either in acids or alkalies; the metals combine readily with chlorine; carbon and the other combustibles become soluble by combination with each other, and with oxigen, or chlorine, or iodine; and we may reasonably presume, that as these bodies came from the hand of the Creator, they were in a condition to act with intense energy, and that innumerable solutions, decompositions and precipitations, took place at a period when elementary action had full play, and the great agents, encountering each other at every turn, gradually developed the new order of things. It is of course difficult to say, precisely what was the condition, and what were the qualities of that early ocean, that primitive abyss, whose existence and sway it is impossible to deny; for while decisive facts declare it to the mere philosopher, revelation unfolds it to the believer, and both conspire to establish the truth in the minds of that large and respectable class of individuals, who combine both these characters in one.

It appears then that the solubility of all the existing materials that form the crust of the globe; their solubility either in their elementary forms, or in their proximate or complex combinations, is a truth clearly demonstrable, and actually demonstrated; and that the only serious difficulty is found, in attributing to the quantity of waters that now exist, *within our knowledge*, sufficient power to suspend all the materials of those rocks, that bear marks of deposition from a state of chemical solution.

On this point, perhaps nothing satisfactory can be said; but we may ask, who knows what were the depth and the quantity of the waters of the primitive abyss; how much water might (as the formations were going on) have been exhaled, even to other regions; how much might have been decomposed to afford the noble, and almost universally diffused elements, of this fluid, to the various nascent bodies, into whose constitution oxigen and hydrogen were destined to enter; and how much might have been received into cavities* in the earth, to await a future call, to deluge the surface anew.

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* We may have occasion to mention again the idea of cavities in the earth, a supposition which some may think is excluded, by its high specific gravity. There is, however, no incompatibility in the two opinions. The amount of water requisite to cover, half a mile deep, all the existing mountains, would occupy

It is worthy of observation, that quartz, feldspar, and mica, the minerals which form the greater part of the three most important primitive rocks, namely, granite, gneiss, and mica slate, are composed mainly of silex and alumine. Now the silex, especially in a state of minute division, is entirely and readily soluble in the fixed alkalies, and so is alumine, with even greater facility: alumine is also very readily soluble in acids; silex is soluble in fluoric acid, and can become even gaseous in that acid, and, if minutely divided, it is soluble in some other acids. Modern analysis has discovered notable quantities of potash and soda in both feldspar and mica; and fluoric acid in the latter, so that it is proved that the necessary solvents were actually present at the time of the formation of these minerals, and therefore entered into their constitution. Alkali exists elsewhere also, in sufficient abundance for the solution of silex and alumine; for that portion of alkali, which is now in solid combination in the minerals, that enter into the constitution of the primitive rocks, would have done but little towards the solution of the earths in question.

The activity of most of the early chemical agents, and of all of them if subjected to pressure, would have been much increased by a high temperature. There can be no reason why we should suppose, that those causes* which now feed the fires of nearly two hundred active volcanos, were dormant in the youth of the planet. On the contrary, the numerous extinct or quiescent volcanos, of unquestionable character, record with irrefragable evidence, the energy and extent of primeval fire, operating both as an auxiliary to solution, and in its own proper agency by fusion; and that, without taking into view the trap rocks, which, if finally

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but a small fractional part of the cubical contents of the earth, (only $\frac{1}{263}$ part) and the remaining solid parts may still be sufficiently dense to give the required specific gravity. The supposition is more at war with the hypothesis of central igneous fluidity; but even these two suppositions are still reconcilable.

* Causes which will be considered under the head of volcanos.

admitted to have had an igneous origin, will greatly fortify this view of the subject.

When the planet was covered by an aqueous abyss, all volcanos must have been submarine, as many now are. They would all therefore act under vast pressure, a pressure incomparably transcending any thing effected by modern experiment, and the heat thus accumulated must have given any desired activity to water and to watery solutions of the great chemical agents.

While therefore provision is made, in this manner, upon established mechanical and chemical laws, for solution on the greatest scale of magnitude, and with the greatest possible energy of action, we may suppose chemical depositions to have been going on contemporaneously or subsequently, either confusedly, as in granite, or in successive layers, as in gneiss and mica slate ; and the imbedded minerals of the primitive rocks, the garnets, the staurotides, the tourmalins, the beryls, and others, were doubtless, contemporaneous crystalizations ; their elements being in solution in the same fluid, and uniting by the force of their peculiar affinities, formed the minute bodies, the integrant atoms, whose concretion ultimately produced the various crystaline solids, which adorn the early formations of the globe.

Water and fire and pressure and all the great chemical agents may thus have conspired, as means in his hands, to execute the great purposes of the Creator, in effecting the arrangement of the crust of the planet.

It becomes easy also to admit that all those catastrophes, which can reasonably be attributed to this period, may have happened.

Igneous agency, the parent of earthquakes, acting beneath the rocks already formed, and beneath the incumbent abyss, might produce fractures, heavings, dislocations and distortions, tortuous flexions, injections of veins and dykes, subsidence and elevation of strata, and all the irregularities technically called *faults* by the miners. Even the trap rocks themselves may have been thrown up beneath the primeval ocean; they may have broken through the strata and congealed above or between or among them, in ridges, peaks or flats; or they may have been injected in dykes or veins, or been driven, laterally, between the strata, rending them asunder, as if cleft by wedges.*

Although in giving this concise sketch of the possible and probable qualities, powers and effects of the primeval abyss, we have endeavored to adhere closely to acknowledged facts and principles as established by experience and sound reasoning, we do not pretend to claim for our speculations the verisimilitude of history. But, the only credible history which exists furnishes a record, important alike to philosophy and religion; we find in the planet itself, the proof that the record is true; we examine by the light of science the *modus operandi* and we think we can trace its development; although we do not confidently aver, that the events actually happened as we have supposed, we endeavor to prove, that the constitution of things and the records of evidence, which the planet affords, accord with our supposition. Thus we honor the Divine Author by tracing the operation of his laws; we would not slur them over under the vague term of *nature*, while we admit not only creative power, but arranging wisdom.†

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* These remarks have reference of course, to the trap rocks that appear in primitive regions, but it is obvious that a similar train of reasoning is applicable, *(mutatis mutandis)* to the trap rocks which are associated with the more recent formations. If these rocks are the offspring of subterranean fire, there appears no reason why their date should be restricted to any one series of rocks, and we actually find them associated with all.

† The author of this sketch is, in no degree, reluctant to avow his full adoption of the Baconian and Newtonian mode of reasoning on natural phenomena, as regards their ultimate connexion with the Creator and Governor of the universe. He would not force moral and religious topics into an unnatural association, with physical subjects, and he thinks it contrary both to good policy and good taste, to act the moralist on every occasion, and thus to render trite and perhaps offensive, ideas which, more cautiously and less frequently introduced, might have left a happy impression. But he holds, with Newton, that Natural Philosophy sustains an indissoluble connexion with the Deity, as the first cause of all things, and as the final cause which must forever terminate every series of secondary causes, by which we attempt to account for natural phenomena.

This reference is therefore not less proper on physical than on moral subjects, although the liberty should be more sparingly and cautiously used. Surely, if on any subject of natural science this course is proper, it is in relation to geology, one of whose primary objects, is to trace the operation of the Creator's laws, in the arrangement of the crust of the planet, which is our present abode.

II. *The rocks in question, namely, the primitive, lie below the others, and therefore were deposited first;* they generally succeed each other, in a certain order, supporting the superincumbent rocks, but they still occasionally break through them all, and rise, so as form the highest peaks and ridges of our globe.

It is self-evident that the lower the rock, the older it must be, just as the foundations of a house must be deposited before the superstructure can be added.*

A miracle, it is true, could substitute one rock for another, but we are reasoning from established natural causes, and not from miracles, and we know not of any cause that would force one rock into a position beneath another, except volcanic or igneous agency, which, it is admitted might do it to a certain small extent, but never on a great scale. Circumstances would also indicate the catastrophe, such as the marks of violence and the altered appearance which the neighboring rocks would exhibit. Except the single case of intrusion by volcanic power, it would be equally true of deposition, from any cause whether aqueous, mechanical or igneous, that the upper rocks must be the most recent.

It is quite superfluous to say, that several rocks may have been deposited at once; it is true that several may have been deposited from the same general agencies, constituting a suite or formation, but it would still be true that there would be succession, either tardy or rapid.

III. *The primitive rocks contain no organized bodies;* not a fish or a shell, a plant or any thing ever endowed with life, or any fragment, relic or impress, of any such body is ever found in them; this fact, with others to be mentioned afterwards, evinces that the fundamental rocks were deposited before the creation of living beings, and that this substratum was laid for the purpose of preparing the globe for its great destination—that of becoming a suitable habitation for beings endowed with life.

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* Contemporaneous crystalization might happen through large masses of the same species of rock, but is not credible with respect to successions of rocks of different kinds, as of saccharoidal limestone in gneiss, serpentine in clay slate, &c.

Even igneous depositions, it would seem, must require succession; one igneous tide bursting through, after another had flowed and congealed; and an igneous rock forcing its way, in fusion, through rocks of unquestionable aqueous or mechanical origin.

Who would believe, for instance, that the greenstone trap of Salisbury Craig at Edinburgh, or of the East and West rocks at New Haven, (Connecticut,) was not deposited after the sand stone and conglomerate rock upon which they repose!

This argument is of a negative character, but still it appears to be conclusive, and it would be conclusive to any extent; for, were all rocks destitute of organized remains, it would be equally fair to conclude, that they were all deposited before that interesting epoch in the creation, when life began to appear upon the planet.

The argument then, respecting the relative antiquity of the primitive rocks becomes still stronger, when we have ascertained that there are numerous rocks which contain organized remains both of animals and plants, but that they are never the lowest rocks, and that they are rarely highly crystaline in their structure, at least they are not often so in a degree to make them compare with the rocks that lie still lower.

But suppose that a rock having a constitution like that of the primitive, should be found lying upon another which is decidedly not primitive, for example granite on limestone containing organized remains; shall we continue to call this upper rock primitive? Certainly not. We must then either give it a new name and refer it to a new class, or allow that there are rocks of that particular name, which are not primitive but of a more recent date.

Such is the granite discovered by Von Buch in Norway near Christiania, provided there be no mistake. It is said to be a true granite reposing upon a limestone containing orthoceræ and other indubitable animals. Allowing the reality of this so called granite, it is a solitary case, and need not therefore disturb our general arrangement. If it be an exception it doubtless had a particular cause.

But should we find granite containing fish or shells or plants, would it be a primitive rock? Clearly not. We should then as before, either conclude that it was not granite, or we should allow that it was a transition or secondary granite. No such granite has however been discovered and probably none ever will be.[*]

IV. *The fundamental rocks are rarely horizontal;* they are usually inclined more or less to the horizon, frequently at a high angle, and sometimes they are found vertical, that is, their strata are on edge; but the progress of research has evinced, that the rocks of the different classes are *occasionally* found in all positions.

It is no longer considered as true, that position, in relation to the angle formed with the horizon, is decisively characteristic of the different classes of rocks. Still the distinction is not entirely abolished, nor entirely without utility. Secondary rocks are usually horizontal, or not many degrees from that position; primitive rocks are perhaps always inclined, often highly so, and almost never quite flat, and the transition strata are generally in an intermediate position. In the formations of North America, it is however much more common to find primitive rocks at low levels, and at moderate angles of elevation, than in Europe.

In observing rocks, their position with regard to inclination, is always to be taken into view, but it would be unsafe to rely upon this character alone. The mineralogical constitution, geological connexion, and extraneous and other foreign contents of the rock, (if any are present,) must also be taken into account in judging of its geological character.

V. *The fundamental rocks are called primitive*, by some primary or primordial, in allusion to their relative antiquity; in geology, this fact is always determined by their position and constitution.

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[*] Rocks consisting of the ruins of granite, are sometimes mistaken for true granite, and it requires some experience to avoid being deceived. A few years since, I received an account, from a remote interior state on this continent, of granite containing bituminous coal and fossil wood. I could not admit the correctness of the observation, and accordingly discovered, on receiving specimens of the so called granite, that the rock was a sand stone made up indeed of quartz, feldspar and mica, but merely in the state of loose and mechanical aggregation, constituting a genuine sand stone, which had probably been formed from the decomposition of granite.

The term is not intended to involve theoretical considerations, any farther than it designates *order of time;* and whatever theoretical views we may adopt, we must admit not only time, but order of time. As to the amount of time, geology alone is not in a condition to decide absolutely; judging from phenomena alone, different events or effects would require periods of very different length.

If we could admit that granite, for instance, might crystalize through a very great space, in a short time; it would still be incredible, that granite and its cognate rocks, gneiss and mica slate, and clay slate; then graywacke and other early fragmented rocks; then anthracite coal, with transition slates, containing impressions of fern leaves and of trilobites; then transition limestones, with orthoceræ; encrinites, and corals; then bituminous coal, with slates containing fish, and sandstones containing culmiferous plants; it would be quite incredible, that all these widely different deposits, should have been produced, by the same state of things, and laid down at the same time.

VI. *The principal primitive rocks are granite, gneiss and mica slate* and other slaty rocks, granular limestone, &c. and they generally occur in a particular order, granite being lowest.

It is not intended on this occasion, to enumerate all the rocks, or to describe any of them minutely. In studying geology, it will probably be found the most convenient and intelligible course, to pursue a particular rock through its entire history, and thus to present a connected view of it, rather than to mention it, in part, under the primitive, then again perhaps in the transition, and then again in the secondary and even in the tertiary.

Limestone is in this condition.

We find it indubitably primitive, then transition, then secondary and lastly tertiary, and its ruins are sometimes found even in alluvial or diluvial regions. Slate has similar characters. The fragmented rocks are found in all the classes except the primitive,* and so of other rocks in a greater or less degree.

VII. *The epoch of the deposition of the primitive rocks appears to be coincident with that of the early prevalence of a primeval ocean.*

This abyss of waters which existed at an early unknown period, before the time of the final arrangement† of the surface, which preceded the creation of man, and continued, we may suppose for an unlimited time, is just such a state of things as is demanded for the deposition of the primitive rocks, and such an one as geologists‡ generally, both admit and require. In this period, the primitive rocks were probably deposited, and nothing appears to forbid the admission, that there was time enough for the formation of all their crystals, and for their regular arrangement.

The marks of disruption, dislocation and derangement, which the primitive, as well as other rocks present, justify us in the opinion, that there were occasional catastrophes, interrupting the general order of events, and producing local disorder; thus, *strata*, may have sunk by subsidence, for want of adequate support, or been torn asunder by earthquakes, or lifted by submarine volcanos; these are however subordinate events, and do not radically alter or subvert, although they may modify our general views.

Some however, imagine, that entire mountain ranges, and even entire continents, have been raised by the force of subterranean fire, and there seems, as already suggested, no inconsistency or improbability involved in the admission, that igneous and aqueous agency may have been concomitant and co-operative, and that, by their alternating, and conflicting, and modifying effects, they may have produced the actual state of things on the surface of the globe.

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* Dr. MacCulloch admits sandstone into the primitive, but in this he appears to be nearly or quite alone, and it is certainly very desirable, and also very practicable, to avoid so embarrassing an anomaly.

† Some prefer to consider it as a reformation from the wreck of a former world, or more correctly speaking, from the wreck of a former state of the present world.

‡ This statement requires but little qualification, even as regards the geologists who imagine a vast internal fire, by which the primitive rocks were deposited from a state of fusion, for they are obliged to call in the aid of water for the first deposition of the materials of the primitive rocks, and of course for the secondary.

A vast mass of evidence has been accumulated, and is constantly increasing, which evinces that internal fire still prevails to a great extent in the interior of our planet, and its effects appear to have been the greatest, and the most extensive, in the earliest periods. Volcanic mountains are known to have risen, even in modern times, from the bosom of the ocean,* and permanent islands have been, and are still existing, where, in former ages, the sea raged uncontrolled. The first postulate of the philosophers of fire, is therefore proved to be possible, but, where mechanical causes are largely concerned, it does not follow, that, because an effect of a certain extent has taken place, that therefore one vastly greater has happened.

Trap rocks may have been produced by subterranean and submarine fire, but it does not, therefore follow, that a continent has risen from the deep. If so, either it was accumulated by successive submarine eruptions, or it was lifted, already formed, by subterranean expansion, and in either case, we may ask, whence were the materials supplied; and if supplied from the regions immediately beneath, what fills the void, and if not filled, what more than Roman or Gothic arches, are provided to sustain the enormous weight of a continent, and to prevent its plunging anew into the abyss, and carrying down, like a sinking ship, all that are embarked upon it. Is it arched over, from side to side, of the tremendous cavern, resting firmly upon the abutments of the solid earth? But what security is there, that subterranean fire will not melt these abutments down, and undermine the incumbent continent?

The primitive rocks present to the eye of one who has been accustomed to examine the results of chemical deposition, very decisive proofs of having been in that state of *mobility*, which leaves the particles at liberty, to unite according to the laws of corpuscular attraction; the heterogeneous particles being connected by chemical, and the homogeneous by mechanical attraction. Thus, in felspar—the silex, composed of silicium, or silicon and oxigen—the alumine, of aluminum and oxigen—the potassa or soda, of potassium or sodium and oxigen—the lime, of calcium and oxigen, and the oxid of iron, of iron and oxigen, would be formed, supposing these to be the ultimate elements of the mineral, first by their uniting, chemically, to form these binary compounds; then these binary compounds would still farther unite, but still chemically, to form the integrant particles of the mineral, and these particles united mechanically, by cohesion, would form the mineral itself.

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* In the Grecian Archipelago, near the Azores, &c.—See Am. Jour. Vol. XIII.

The same reasoning may be applied to every variety of rocks and minerals. Limestone, consisting for its immediate principles, of lime, carbonic acid and water, contains, for its ultimate elements, according to the present state of our knowledge, calcium, carbon, hidrogen and oxigen; the latter principle being united with each of the former ones, so as to produce the lime, (oxigen and calcium,) the carbonic acid, (carbon and oxigen,) and the water, (oxigen and hidrogen.) If the limestone were a magnesian one, then we must add oxigen and magnesium, and so of other earths, as silex or alumine, if they were present.

How far back, and how near to the isolated, independent state, we are to trace each element, we cannot determine. Whether the elements were created, in the first place, in a state of perfect freedom, and their earliest movement was, not so much, that of elemental war, as of elemental combination; or whether, they were combined in pairs, and those pairs again combined, to form more complex results, we can never know with certainty; and all our suggestions on this subject being necessarily hypothetical, ought of course to be concisely stated.

But the discussion of these questions, which might easily be extended to the most complex rocks, and to all their imbedded minerals, however curious and even interesting, is, in no way material to our proceeding to reason intelligibly—may we not say plausibly, or even conclusively, upon the act or process, which must, according to physical laws, have preceded the concretion of the materials of the primitive rocks.

Suppose the elements which are to form granite, to have already united, and the previous fluidity, whether of solution or fusion, or both, to have established a state of things favorable to the grand result, the formation of the different minerals, a simultaneous deposition must of course happen ; the quartzy particles must find their fellows, those of feldspar will do the same, and those of mica the same, and the three minerals, born at the same moment, will find repose in the same cradle. In the same manner, their ornamental companions, (not essential to the rock, but often studding it, like gems set in royal robes)—the emeralds, the topazes, the garnets, the tourmalines, and the other crystalized minerals which sparkle in the bosom of the primitive rocks, declare a common birth. True it is, that creative power could call the rocks into being, without any arranging process in their parts, but no analogy countenances the truth of such a supposition, and neither moral nor physical reasons oblige us to admit so improbable a supposition.

Who has contemplated the stupendous garnets of Fahlun—the equally gigantic quartz and felspar crystals of the Alps—the more delicate emeralds of Brazil and Ethiopia—the variously colored tourmalines of Chesterfield, and Goshen, Mass., and of Paris in Maine—the fluor and calcareous spars, of Derbyshire and Cumberland—the idocrases of Vesuvius, and the rubies and sapphires of Ceylon and other regions of India, the bubbles of air included with water and other fluids in quartz—the fibres of amianthus—the crystals of titanium—the filaments of native copper and silver shut up in the same mineral—the successive crystalizations of galena—sulphate of barytes—calcareous spar—quartz and fluor spar, often included in the same group—the splendid amethystine and other geodes—little grottoes lined with polished and beautiful geometrical figures—who has seen all these things—the ornaments of our cabinets, and has doubted that they were as truly the results of crystalization, as any of the products of art, which are formed in our laboratories?

Crystalization is indeed not exclusively the attribute of primitive regions; but in such regions it is eminently conspicuous, and if we find crystals in the productions of every geological age, we are thus furnished with proof, that these agencies continued to operate, although with diminished frequency and energy, through all succeeding periods, and that they have not ceased even in our own times,[*] for mineral crystals are, every moment, forming around us.

Still no one finds in the upper secondary rocks—much less in the tertiary, the numerous and grand crystals that are common in the primitive, and even to a degree in the transition formations, and no one looks for those grand crystal cavities, *fours a cristaux*, as they have been fancifully called,[†] except in the ancient mountains, and in the veins and beds by which they are intersected.

No person who has been conversant with the effects of solution, and especially of solution, aided by heat and pressure, can easily confound them with those of mere mechanical deposition. Take a piece of the most beautiful granite—its quartz is translucent if not transparent—its feldspar is foliated in structure, presenting two regular cleavage planes, united at definite angles —its mica is perfectly foliated, and splits into innumerable thin laminæ, each of which, is perfectly transparent and has a high lustre, and this last property is common (sometimes in a less degree,) to the quartz and the feldspar. Gneiss and mica slate and saccharoidal limestone are distinguished, in a greater or less degree by similar characteristics. Now, translucency—transparency—lustre—cleavage, planes and regular structure, are known and established results of chemical deposition, and are never the effect of mechanical aggregation. Compare the above properties, with those found in a piece of clay or chalk, and no person, however unskilled in physical characteristics, can possibly attribute them to a similar origin. The latter have as obviously sprung from mechanical as the former from chemical laws;—mechanical suspension must have preceded the one, and solution, fusion or sublimation the other.

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[*] I have obtained crystals of calcareous spar—of sulphate of barytes and of sulphate of lime and some of them repeatedly as accidental results in chemical processes: I have seen even quartz crystals form rapidly under my eye, and others have cited them as slowly produced with regularity and beauty, from the fluoric solution of silex. Crystals of pyroxene—specular iron, titanium and other minerals have been produced by volcanic and furnace heat; more than forty species of minerals have been observed in the slags of furnaces, and white pyroxene has been produced by the action of fire upon the constituents of this mineral, and after fusion, it has recrystalized, in the same form.—*Am. Jour. Vol.* 10. *p.* 190.

[†] Patrin's mineralogical travels.

Crystalization is the most exalted agency of the mineral kingdom and it answers to organization in the animal and vegetable; but it is entirely unconnected with the principle of life. It results in the production of regular solids—often of beautiful figures, bounded almost always, by plane faces and by right lines, which constitute the outline of beauty in the mineral kingdom, as the curve line does in the organized kingdoms. (Haüy.)

VIII. Geological research clearly proves, that *the earth was gradually redeemed from the universal and long continued dominion of water* under which it lay at its first creation. The appearance of the *dry land*, necessarily implies previous *entire* submersion, and taken in connexion with the existence of the universal watery abyss, before described, necessarily implies all that geology requires on this part of the subject.

The tops, the peaks and ridges of the highest mountains,* began then to appear, as they emerged from the universal primitive ocean, and as its waters gradually retired, the land became more and more denuded, and at this period and not before, it became possible, that vegetables should begin to exist, because they had now a place and soil on which to grow.

It is *possible* (but there is perhaps no positive evidence of the fact,) that some aquatic plants might have been created a little earlier, but the primitive ocean was evidently then too much charged with mineral matter to afford a proper medium, or a proper pabulum, for any considerable extent of animated existence, either vegetable or animal. As its waters were, gradually, more and more freed from foreign matter, by the progressive deposition of the rocks, it began to be fitted for the simpler forms of animal life, and its qualities might not have been inconsistent with the existence of some species of aquatic plants; still, we believe that the earliest impressions of vegetables, found in the transition strata, are generally those of land plants, or of those which might grow on shores or in swampy or marshy situations.

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* It is not material here to discuss the origin of mountains—whether they were raised from below, or left prominent by the subsidence of the contiguous regions, or were reared by accumulation; it is agreed on all hands that they existed before the subsidence of the early ocean, whose retreat must of course have first exposed their summits.

Plants are not numerous in the transition strata; as far as they were littoral, aquatic or marine, and therefore vegetating in or near the water, they would be found in the deposits of stony matter that were embosomed in it; as far as they were terrestrial, they might have been swept in by winds, storms, tides, and currents, and would thus become entombed. As to the animals, they, being altogether aquatic and marine, must necessarily live and die in the water, and their remains would be consolidated in the rocks whose deposition was then going on.

TRANSITION ROCKS.

IX. *The rocks deposited at and immediately after this period, are generally less crystaline and more compact in their structure than the primitive.*

The crystalization, although often conspicuous, is more confused; in the transition limestone, it sometimes appears only in minute plates and spangles, but the translucence is usually preserved, especially at the edges.

The number of foreign and imbedded crystals is less considerable than in the primitive rocks, and we begin to find the first proofs of certain modes of mechanical agency, indicating the commencement and earliest effects of attrition and violence upon the rocks already formed.

We must not confound these mechanical effects with those already mentioned in relation to the primitive rocks, among which we find so many proofs of sudden and great violence, causing ruptures, dislocations and injections of foreign matter; the rocks are elevated, contorted and fractured; veins and dykes are introduced cutting the strata ; some of the strata are below and some above the common level or plane of the same strata continued, but the rocks are generally in or near their original geographical location, and pebbles, gravel and bowlders are rarely found.

Still, in our artificial arrangements in geology, we must remember, that near the dividing lines of contiguous departments, there are mixed characters. In rocks, decidedly primitive, we find (especially where a later formation is about to commence) marks of mechanical agencies, fragments of primitive rocks, and entire and sometimes large masses, imbedded in a basis of primitive rock.*

X. *In these rocks, we find (in general) for the first time, fragments both rounded and angular of all the previous rocks ;* sometimes these fragments are united by crystaline matter, forming the paste or cement, which holds them together ; at other times, the paste is composed of nearly or quite the same materials with the fragments, but in a state of much finer division, and at other times there is little interposed cement.

We must not confound the crystaline with the fragmentary or brecciated rocks, although some rocks of the transition class are almost entirely crystaline, and others are made up chiefly of ruins assembled and cemented.

In the formation of the transition rocks, chemical and mechanical action appear to have been sometimes concomitant, and at other times, alternating.

Among the transition marbles, which are decidedly crystaline, we may mention the limestone of the peak of Derbyshire, and the imbedded animals also, are often crystaline in their structure. Many of the transition limestones may be called at least sub-crystaline. The marbles of Bennington, Middlebury, and Swanton in Vermont—the latter on Lake Champlain, are translucent at the edges and evince a previous state of chemical solution ; those of Hudson, N. York, are similar and abound with encrinital remains.

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* The country about Northfield and Montague and Gill's falls in Massachusetts, presents remarkable examples of this nature, and they are the more interesting from the fact that we can, in the course of a few miles, trace a progress from rocks decidedly primitive, to conglomerate and even to graywacke and sand stone.

But many of the rocks of this class are most palpably fragmentary, and the fragments are of all sizes, from those that are scarcely visible to the naked eye, to those whose dimensions are measured by inches and even by feet.

The graywackes of the Chaudière falls in Lower Canada, of Rhode Island, and of the Cattskill mountains, are striking examples.

The brecciated marble of the Potomac, employed in the public buildings at Washington, seems to belong to the transition class. It is a remarkably firm rock, composed of ovoidal and angular pebbles, which appear to have received their shape from friction in water. The cement is a more minutely divided substance of the same kind, but calcareous matter is not exclusively the material either of the pebbles or of the cement.

The fragmentary rocks of Rhode Island, extending by Providence to Boston, and which are very conspicuous in Dorchester, Roxbury, Brooklyn, and other neighboring towns, are fine examples of early formations of this kind. They are very interesting five miles east of Newport, at a place called Purgatory, where a large mass of the rock, separated by the natural seams which are found in it, running parallel for a great distance and cutting the pebbles in two, has fallen out, having been undermined by the sea, whose waves, when impelled by storms, break and roar, frightfully, in this deep chasm.

The pebbles are here chiefly quartz—they are ovoidal in form and of every size from that of a bird's egg to that of a common keg, and they lie generally with their transverse diameters parallel.

The pebbles of the fragmentary rocks about Boston are very various in their composition, obviously however the ruins chiefly of primitive rocks. The pebbles, which there lie in the roads and fields, have proceeded from the disintegration of this pudding stone. Although to estimate comprehensively, the extent and variety of fragmentary rocks, we must include in our view the vast deposits of the periods later than the transition ; still we may pause a moment, at the geological period now before us, and enquire whence arose the mighty masses of ruins which, of every shape and variety of composition, compose, not merely accidental fragments, or here or there a stratum or a hill, but which cover myriads of square miles, are sometimes the basis of countries, and rise occasionally even into mountains. The Cattskills are conspicuous monuments of geological revolutions. Not only at the base but at the summit, thousands of feet above the level of the Hudson river, we find these mountains composed extensively of fragmentary rocks, rounded and angular, and their rude piles inform us, that the materials of which they are built were once loose and rolling about, in the waves of the early ocean, encountering friction and violence, in their various modes of action.

If we call to mind the sketch recently presented to us of the effects and proofs of crystalization, as exhibited in the early primitive rocks, the contrast afforded by the fragmentary rocks, must appear very striking, and connected with their relative position, can leave no doubt on the mind, that they arose from a subsequent and totally different state of things.

What were the causes that broke up portions of the primitive rocks and left their ruins the sport of the waves, destined, in the progress of time, to be cemented again into firm masses?

Beyond the wearing effects of powers still in action, those of the weather and the seasons, and of the vicissitudes of temperature, we are at liberty to add the convulsions of earthquake, tempest, flood and fire, by which our planet is still agitated. Beyond these we are not at liberty to go, because we have no facts to form certain grounds of reasoning; but the causes that have been named would, in the course of ages, perform the work, great as its results may now appear.

XI. *The rocks of this class are rarely either quite vertical, or quite horizontal in their position;* their strata are inclined often at high angles from the horizon; where their strata come in contact with the primitive rocks, the former are found upon the latter, and when they touch primitive mountains, they generally slope down their flanks; always lying above them, but declining gradually towards the plain countries, and terminating commonly beneath them.

It has been proposed to limit their obliquity between certain degrees, for instance, 10° or 12°, and 45°. It is probable that these boundaries would, in fact, include most of the transition rocks; but it would be inconvenient to restrict ourselves within these limits, because, we do occasionally find transition rocks that range both below and above these degrees. Indeed, the progress of geological investigation has proved, that there is much less reliance to be placed upon the position of rocks in regard to obliquity, than was formerly imagined; although this distinction is not to be abandoned. Alone, it would perhaps rarely serve as a just ground of conclusion, but in connexion with other characters, it is a valuable auxiliary. As to elevation, transition mountains are not the highest, but they often attain a considerable altitude, as in the Cattskills—two, three and four thousand feet: and transition rocks sometimes occupy also low levels.

XII. *In these rocks, we find the first traces of organized beings;* the perfect impresses of plants, and both the impresses and the entire mineralized bodies of millions of animals; the deposition of these rocks was therefore cotemporary with, or subsequent to, the creation and propagation of the organized beings, whose impresses or whose bodies they contain, and it is self evident that these rocks could not have been deposited prior to the date of the animals included in them.

Both the plants and animals lived and died at or near the places where they are found entombed in the rocks; for they present, in many instances, few or no marks of violence, or of accident; their most delicate parts are, often, perfectly preserved; animals, with all their organs entire, and plants with their fibres and leaves in full expansion.

We must not, however, understand, with too much strictness, that every thing was always quiet in that ancient ocean. There is no reason to doubt that there were tides, as the laws of gravity were doubtless the same as now; there were probably storms, and tempests, and currents, and as the land came to be gradually uncovered, there would be rivers and torrents; there were also, we must believe, earthquakes and volcanos; hence, or from one or more of these causes, the marks of violence which we occasionally find, one stratum having its included mineralized organic bodies entire, and a contiguous one having them more or less broken. (Our author, page 24.)

Both the plants and animals, generally belong to races which are no longer found alive, or if *analogous* races exist, they are related to the ancient ones, rather by generic than by specific characters. The animals are commonly either zoophites (belonging chiefly to the coral family) or shell fish, in many instances destitute, or nearly so, of locomotivity; sometimes, however, they are furnished with organs for motion.* Sometimes they occupy great districts of country, and form almost the entire mass of marble, in the bowels of mountains, miles from day light, and they are so firmly united to the rock, as to form part of its substance. Many of the architectural marbles owe much of their beauty to imbedded animals, myriads of which lie almost in absolute contact, the matter of the rock only filling up the void between them, the void occasioned by their angular and confused positions.

There is no difficulty in understanding how the marine animals, the encrinites, for example, that fill the transition limestone of the Peak of Derbyshire, came to be thus entombed. We cannot doubt that the animals received their existence, and lived and died in an ocean full of carbonate of lime, in solution or in mechanical suspension, or both. When they died, they of course subsided to the bottom, and were surrounded, as they lay, by the concreting calcareous matter. Multitudes of them were present at the same time and place, in all the confusion of accidental position, and therefore were enveloped, just as we find them, in every imaginable posture; the interstices were filled by the calcareous deposit, and this being more or less chemically dissolved, produced a firm sub-crystaline mass, a section of which shews us the animals sawn through, and admitting of a polish like the rest of the rock.

If we could suppose that our common clams and oysters, that lie in the mud of our harbors and inlets, were to become solidified into one mass, along with the matter which envelops them, the case would not be dissimilar; only they would be enveloped in earthy, instead of crystaline matter, and the rock formed from it would be referred to the most recent secondary, or to the tertiary.

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* Madrepores and encrinites could move very little; the echinus, found in secondary rocks, moved on his spine, which served him for a foot, and some of the early shell fish had organs to enable them to rise and fall in the water. (Our author.)

It is easily understood, also, how a new stratum, either of the same or of different constitution, may be deposited upon a previous one; and with it, the bodies of the animals that lived and died in the fluid; and these might be the same animals with those of a previous stratum, or of a different species or genus, it being understood that each successive stratum was, in its turn, the bottom of the then ocean, and also the upper or last consolidated layer of the crust of the earth, as it then was at that place.

As we have no direct historical evidence to the facts, it is impossible to say, precisely, what circumstances would determine such an ocean, to deposit, at a particular time, a stratum of limestone with madrepores and encrinites, and then one of slate with trilobites and fern leaves, and then one of breccia or sandstone with stems of reeds or palm leaves, or bodies of pectinites and anomiæ.

But it is easy to imagine, that if all the causes necessary to produce these events, were in successive operation, the events might succeed each other in the order supposed; and that they did in fact so succeed each other, cannot be reasonably doubted, any more than that an edifice, having trap rock for its foundation, and sandstone for its basement, and marble for its superstructure, and wood for its roof, and finished with sheet lead, zinc or iron, was actually constructed of these materials, connected by the builder in that order.

The great truths of geology are few, simple and intelligible; needing nothing but the application of a sound judgment, enlightened by science, to the accurate observation of facts. The facts can often be distinctly observed, and the order of their succession ascertained, whether the proximate causes and the immediate circumstances can be discovered or not. We then reason upon them, with the aid of the knowledge which we have acquired, and there can be no doubt that we often reason conclusively and correctly.

It is a supposition, altogether inadmissible, and unworthy of a serious answer, that the animal and vegetable races, entombed in such profusion, and buried often under entire mountain ranges, or firmly cemented into their very bosom, were created as we find them. On the contrary, there can be no doubt whatever, that they were once living beings, performing the part belonging to their respective races,* and that at their death, or soon after, they were consolidated, in the then concreting and forming rocky strata.

XIII. *The transition rocks are supposed to have been deposited, while the earth was passing from the state of a watery abyss to a habitable condition, and therefore they received the name which they bear.*

The leading rocks of this class are, most of the variegated, fragmentary, and petrifaction marbles, many pudding stones, breccias and sand stones, all the graywackes and many slates, especially those connected with the anthracite coal; such as that of Lehigh, that of Wilkesbarre, and that of Rhode Island, besides other strata.

Some geologists, instead of a transition class, prefer referring these rocks principally to those which we shall next describe, only considering a part of them as the older rocks of that class, and another part as newer members of the preceding.

It is less important which method is pursued, than that the characteristic distinctions of the rocks should be clearly pointed out.

The word transition is also partly descriptive of the characters as well as of the supposed age of these rocks: their characters are generally midway (*in transitu*) between those of the primitive and of the secondary rocks, and we slide down by a pleasing and instructive progression from the one to the other.

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*The trilobite, one of the early fossilized and imbedded animals, could bend his body double, like a lobster, having in his back, the same jointed articulation; we find him sometimes doubled, and sometimes expanded, as he lies in the rocks, and his eyes are often standing prominently out. Grand trilobites, of singular size and perfection, were shown me by the late Mr. John Sherman, at Trenton Falls, near Utica, (New York) where they were obtained. They seemed almost looking out of the black limestone rock, as if still animated.

I am therefore inclined to retain the word and the class transition, although without confining it to the precise limits designated by Werner, who introduced this division.

It is seen at once, what inconvenience is experienced, when we attempt to dispense with the transition class of rocks. We either produce confusion in the primitive, by attaching to it the unnatural appendage of early fragmentary rocks, or we swell the secondary, already sufficiently full.

There is also this additional embarrassment in giving up the transition class. Either we throw into the primitive class, rocks containing organized remains, which creates a very unfortunate blending of formations extremely dissimilar, or we extend the secondary class still more, and group together organized remains of almost all ages, of all indeed, except of the tertiary and alluvial.*

Regarding therefore, for the present, Werner's theoretical ideas as to the *transit* of the earth from a chaotic to a habitable state, in no other light, than as the ground of a classification, we find that it is impossible, without great inconvenience, to neglect those peculiar characters and circumstances which denote an actual transition in the nature and position of the rocks, and which therefore sustain the propriety of this or of some analogous division.

XIV. *Not only the tops and ridges but the flanks of the highest Alpine chains were now, as we may presume, uncovered, and with them a portion of the highly elevated land was brought into view;* the valleys, basins, defiles and plains, with the moderately elevated regions, were probably still covered by the remains of the original ocean, and the waters appear to have been freed from a considerable portion of their chemically dissolved mineral contents; it would seem however that they still retained matter in chemical solution, and much that was in loose fragments or *mechanically* suspended; the latter state of things necessarily must have occurred, because there was now an extensive surface exposed to mechanical agencies. It would however appear that the waters had become much more fitted to support life, and the life of animals of more complex structure, and which demand a purer medium and a pabulum less mineral. Every thing seems now to have been prepared for the next grand epoch.

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* The ingenious division of Messrs Conybeare and Philips, is not chargeable with these inconveniences, and is in many respects very good; but hitherto it is little known out of England, and perhaps it has a happier application in that country, where the coal strata hold so conspicuous a rank, than in most other countries.

The creation of the vegetable and animal races appears to have gone on progressively with the deposition of the mineral strata and masses. It is impossible to form any other inference, if we examine the contents of the terrene crust. The only point that admits of discussion is, as to the amount of time employed. We shall be in the best situation to judge of this after having surveyed the entire subject, including the phenomena of the deluge, which, being the last grand catastrophe, that has happened upon the planet, has left, as might be supposed, its vestigia every where. These appearances and their causes must form a distinct subject of consideration, and no one can reason, correctly and conclusively, upon geology, who does not separate the events connected with the great catastrophe which destroyed nearly the whole human family, and most of the animals, from those events which belong to the earlier periods of the planet and preceded the creation of man.

The geological evidence that supports the history of the flood is most abundant and altogether satisfactory; but it is peculiar, and appropriate, and is very much confused and weakened, by being blended with the facts belonging to the primitive watery abyss, most of which have no connexion with or resemblance to the events, belonging to this period.

Before geology had become a science, it was very natural and perhaps unavoidable, that these effects should be, to a degree, confounded, but the discrimination which divides them and assigns to each the results that belong to it, is, in most cases, no longer difficult, and it is very unhappy, *in every view*, that mistakes should be committed on this subject.

SECONDARY ROCKS.

XV. *From this period there is a progression in the position, constitution and contents of the rocks, which, although it sometimes presents only shades of difference, in contiguous members, is widely diverse in the extremes, and occasionally in deposits of nearly the same age.*

In our artificial divisions of natural subjects, we are liable to do violence near the dividing lines. This is particularly true in geology. If we can hardly separate the later members of the primitive from the earlier members of the transition class of rocks, it is perhaps still more difficult to distinguish accurately between the borderers of the transition and the secondary.

Still, for the sake of perspicuity and for the assistance of the memory, it is necessary to fix the limits between the two.

But the truth is, that there is a gradual and instructive progression from the earliest primitive down through the transition, secondary and tertiary, to the diluvial and alluvial, including the undoubted but anomalous productions of fire, the lavas;—and the trap rocks and some of the porphyries, which, in the opinion of most geologists, had the same origin.

After the geological student has surveyed the whole, he will be little embarrassed by the artificial divisions which have aided him in his research. Having reached the top of the building, he will regard the stages and ladders by which he ascended, not as essential parts of the edifice, but merely as the means of his elevation.

XVI. *The position of the secondary rocks is generally horizontal or nearly so*, varying commonly, but a few degrees from that position. Sometimes however, they are found inclined at high angles, and even, as is asserted, in a few rare cases, in a vertical position.

The truth seems to be here also as with the primitive and transition, that position in regard to obliquity, is not a decisive indication of the character of a rock; still the positions of the rocks are generally those that have been described.

These rocks, where they are found in connexion with the classes before described, generally occupy the lower declivities of the mountains, reposing upon the transition rocks, or if these are wanting, upon the primitive, and they often slope gradually away into the plains of which (if they are present at all,) they form the upper surface; these rocks are not always found on the plains, whose immediate surface is sometimes formed by rocks of the transition or primitive class. But when the three are present at once (which frequently happens) those rocks now under consideration are on the top, the transition are next below and the primitive at the bottom. It is believed that in every country, by perforating to a certain depth, we should always arrive at primitive rocks, but in particular situations, those of either class may be occasionally found on the surface; the newer rocks when absent, either never having been deposited in that place, or having been removed by gradual or by violent operations.

The primitive rocks, form, by far, the greater part of the crust of the globe; they constitute the firm basis of every country. Whether they appear at the surface or not, depends upon the presence or absence of the other classes of rocks.

Either of those classes may at particular places, cover the surface, and should the secondary alone appear, it may be impossible to know whether the rocks, intermediate in character between the secondary and the primitive, (the transition) exist below; but, in general, we may be sure of this fact, that a newer rock will not be found below an older one.

It may happen, as in Saxony, and many other countries, that the several classes of rocks may be exhibited in regular succession, the older rocks breaking through the newer and exposing portions of their masses uncovered.

It may, even happen, that the peaks and ridges may be primitive, the higher slopes and flanks transition, the lower secondary or tertiary, and the plains and hollows diluvial or alluvial, with perhaps an interlude of trap, or porphyry, or trachytic rocks, intruding among the rest, or crowning some of them; but this regularity of order is rarely found in full detail.

XVII. *The rocks of this class are called secondary, in relation to the supposed period of their deposition.* They occupy some entire countries, covering the primitive and transition classes. They are not always confined to plains and basins, but frequently rise into hills; sometimes even into mountains of moderate elevation, and frequently, they form what is called a rolling surface.

Secondary countries constitute a very considerable part of the earth's upper surface. A vast tract, mainly secondary—some of it perhaps mounting to the transition—extends from the western slopes of the Alleghany mountains to the Rocky mountains, forming one of the largest surfaces of derivative rocks in the world.

On the contrary, extensive ranges of the Alleghany mountains, running parallel with others of the secondary and transition class, are primitive, and primitive rocks occupy the surface of a very large part of the eastern or New England states.

Consequently, as in other regions, the scenery, the building materials, the soil, the agricultural processes and productions, and the very manners and modes of life of the inhabitants, vary with the physical features of the country. This is true also of the water courses and water power, the qualities of the water, and to some extent, of the very aspect of the sky.

XVIII. *Their constitution is progressively, less and less chemical, and more and more mechanical, in some degree, according to their age;* the older members of the series contain considerable traces of crystalization, but the newer are often quite earthy, and composed of finely divided parts, aggregated with little or no crystaline matter between the portions. The transparency, lustre and pure bright colors; the numerous aggregated and imbedded crystals, and the delicate structure of parts so conspicuous in the older rocks, are almost entirely wanting, in the most recent secondary. When crystals are found, they have generally resulted from the infiltration of fluids, subsequently to the formation of the rocks, and therefore the crystals occupy veins and cavities, and the mass of the rock is commonly destitute of them.

The agency of subterranean fire may have produced many crystalizations, especially in the ignigenous rocks, and we are not to suppose that all crystals have originated from aqueous solution. It has been proved, as well by the crystals produced by fire, in the case of volcanic eruptions, as by those which are occasionally found in the furnaces of the arts, and in heated and ignited vessels in our laboratories, that heat can form these beautiful solids; but, in general, there appears no reason to suppose that secondary rocks have been exposed to heat; and we look in vain for the splendid imbedded crystals, as well as for the general crystaline structure, by which the earlier primitive rocks are distinguished.

Who expects to see in the sandstones and shales, and in the compact limestones, that display of crystals, which is so common in the primitive?

We must not, however, attempt to limit natural operations too strictly. Every thing is not chemical that is early, nor every thing mechanical that is late. In the progressive development of the present order of things, there appear to have been alterations, and successions of periods characterized by chemical and mechanical deposits. The fragmentary rocks begin very early, immediately after the primitive, and even, perhaps, with the latest of that class, and they continue through all the formations, down to the alluvial and diluvial. Their deposits are, however, often interrupted by chemical formations, and therefore we still find chemical deposits, even among the secondary, and mechanical among the transition. This, however, does not seriously invalidate the truth of the general statement, that the higher we mount in the ages of rocks, the more chemical they are in their composition, and the lower we descend in time, the more mechanical.

It is generally true, that the lower the position of a rock, the deeper it lies in the earth, the more chemical is its constitution, and the more superficial, (provided the several classes of rocks be present at the same place) the more mechanical it will be found. These truths, originally developed by Werner, have been, in part, questioned or denied by Dr. MacCulloch, upon the evidence of the strata, contained in a very limited, although a very interesting district, the West of Scotland; but the structure of the United States, and generally of North America, greatly confirms the original view of the geologist of Friburg.

There are splendid crystalizations in the transition and earlier secondary limestone, as in Derbyshire, and at Lockport and Niagara, in the State of New York. In the two latter places, although the rocks are usually called secondary, and lie very flat, there is a strong approximation to the transition character.

XIX. *The secondary rocks are often composed of palpable fragments, being the ruins of the preceding rocks.*

Many breccias and pudding stones, and a vast variety of sandstones, are of this description; and whether they are older or newer deposits of this kind, that is, whether they are referrible to the transition or secondary rocks, must be decided by their appearance, relative position, contents, &c. The most recent secondary deposits are scarcely to be distinguished, except by their stronger aggregation, from clays, soil and sand, and other merely earthy masses, of the tertiary or alluvial.

Indeed, the tertiary class, introduced within a few years, completes the connexion between the secondary and the most recent deposits.*

XX. *The secondary rocks, as a class, abound with organized bodies, and with their relics and impresses.*

It is not true, that *every* secondary rock contains such remains, nor that the same rock is always characterized either by their presence or absence; but, secondary rocks often contain organized remains, in astonishing quantities.

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* Some persons have urged that the term primary should be applied to the primitive rocks, secondary to the transition, and tertiary to the secondary. This would no doubt be, *numerically*, more correct, but it would not now be judicious to disturb the received acceptation of words, which really convey no false idea, and we should lose the advantage of the word transition, which is very significant, and in the sense which has been explained, its use is very just. Besides, a frequent change of terms is a great evil, and it is one of the vices of the science of this age.

The older rocks of this class, generally abound in shells of molluscous animals, principally of extinct genera, and there is a progression through the more recent strata, exhibiting a greater and greater approximation towards the more complicated structure of the most perfect animals; and the newer rocks of this class, and of the strata that lie upon them, including the tertiary, contain reptiles, fish, and even birds, and some terrestrial quadrupeds. Within a few years, however, the skeletons of some very large oviparous animals of the crocodile family, namely, the ichthyosaurus or fish lizard, the megalosaurus or great lizard, and the plesiosaurus, have been found in the lias limestone of England.

The secondary rocks abound with the impressions of plants, and there is, with respect both to them and the animals, a gradual progress from those which are unknown, or little known at the present day, up to those that are similar to, or identical with, the existing races. Many distinguished geologists entertain the opinion, which is sustained by numerous observations, although, perhaps, not absolutely confirmed in its fullest extent, that the same rocks, either of the transition or secondary kind, contain, when they have any such relics, organized remains of the same species or genera of plants and animals, so that a given rock, in the most remote countries, exhibits, as is supposed, substantially the same relics, and therefore it is inferred that the deposition of these rocks probably arose from the same causes, and was attended by similar circumstances. If this position is not fully established, so considerable an approximation has been made towards confirming it, that the fossil organic bodies contained in rocks, are now considered as good indicia of the geological age and character of the strata in which they occur.

It is to be observed, that, excepting in the coal formations, the remains of plants are much less numerous in the rocks, than those of animals; and among animals—until we arrive in the most superficial, and the most imperfectly consolidated rocks—the greater part, both in the transition and secondary formations, are marine or aquatic.

It is easy to understand why plants are less frequent than animals. Until the latest periods of the redemption of the earth from the dominion of water, there must have been a much less perfect accommodation of things to vegetable, than to animal life, and therefore it might be expected that the impresses of plants should be more rare than those of animals.

They are few in the transition rocks, and, in that class, they are most frequent in the strata connected with the anthracite coal.

Among the secondary rocks also, they are most abundant in the bituminous coal formation, and they increase in quantity and variety, as we approach the tertiary, in which, and the most recent secondary, they are numerous; and we end by finding inhumed wood in the form of lignite, or bituminized wood, or wood slightly mineralized; and eventually we find wood unchanged; and thus we trace the vegetable families, from their commencement on the borders of the primitive, quite down to our own times.

The remarks that were made on the fossil animal remains of the transition class, are, in a great measure, applicable here. As the earlier animal races were evidently produced, lived, and died, in the water, and as even many of the more recent were amphibious, we cannot be surprised that their remains should have been deposited in the bottom of the then existing ocean, where they appear to have been consolidated, along with the matter of the rocks, which was in the course of deposition around them. Their deposition was evidently progressive; and successive generations, either of the same, or of different species and genera, were, in their turn, entombed and mineralized, and thus prepared for exhibition to the men of remote ages, who should chance to look into the natural mausoleums containing them.

The testaceous animals, being already protected by a natural calcareous covering, needed to be changed only in the interior or living part. Sometimes this is petrified with the same mineral matter as the shell; at other times, the shell is calcareous, and the animal is silicified; this is the fact, particularly with many of the chalk fossils; the echinus and the alcyonia are often masses of flint, still, however, retaining the organized form, while every thing around them is calcareous.

It is scarcely possible to doubt, that the process of animal and mineral deposition, which has been thus concisely described, was that which really happened. Whatever may have been the operations of fire, at preceding or subsequent periods, it is impossible that it should have been concerned in the first deposition of the mineral strata, containing organized remains. Indeed, no geologist, however inclined to attribute as many things as possible, to igneous agency, has supposed that animal or vegetable life could ever be produced or sustained in the midst of fire; and indeed, it is quite incredible, that strata, containing distinct organized remains, were ever melted; nor is it easy to imagine that they could be even softened, in any great degree, without destroying or materially deranging the organized texture.*

XXI. *It appears evident that the mineralized plants and animals of the solid strata have not been collected in these situations, by any sudden and local, or even general catastrophe,* for as an author remarks, "among the immense number of fossil shells, many are remarkable for their extreme thinness, delicacy and minuteness of parts, none of which have been injured, but on the contrary are most perfectly preserved." Among the plants of the coal formation situated sometimes hundreds and thousands of feet below the surface, and covered by many beds of solid rocks, their leaves, many of which are of the most tender and delicate structure, are found fully expanded, and in their natural position, in regard to the rest of the plant and laid out, as it were, with as much care as in the *hortus siccus* of a botanist. The minutest parts do not appear to have suffered attrition or injury of any kind.†

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* Organized remains, or more strictly, petrifactions, have been beautifully named, the medals of the creation. Laid by, in ancient and progressive time, in the bosom of the deep, in which the rocks, containing them, were formed, they furnish a perpetual incentive and reward to investigation.

† To the truth of this remark, there are of course exceptions; there are disordered strata and aggregates, upon which are impressed marks of violence, exerted, ei-

It is evident therefore, that notwithstanding partial and local exceptions, the general state of things, at the time of these depositions, was favorable to the quietness of animal and vegetable life, and to the preservation of the remains of both kingdoms.

XXII. *Without excluding the possibility of transportation in particular cases, there can be little doubt, that in general these plants and animals lived and died at or near the places where their remains are found, and that at least those which are mineralized and entombed in the rocks, have no connexion with the deluge.* "Compare the calm deposit of shells and the appearance of the still calmer death of the antediluvian vegetable world with the bowlder stones, the gravel and the disjointed, dispersed and fractured osteology of the diluvial deposits, and it will be allowed that there is not the slightest analogy between these classes of events." (Sir A. Creighton in Annals of Philos. Feb. 1825.) We repeat, that it is a great error to attribute the remains and bodies of plants and animals, found usually in a mineralized condition in the mountains, and rock masses, often occupying extensive districts and sometimes whole countries, and unfathomable depths, to the punitive deluge. In past times, this error was quite universal, and it is not surprising that it was so, when we recollect that geology, as a regular and rational study, does not claim a date beyond the middle of the last century, and its more accurate researches and reasoning may be considered as almost exclusively the offspring of the present century.

One of the most important results obtained by modern geology is, that it has clearly distinguished between the circumstances, object and effects of the primitive abyss and of the diluvial ocean; and no two allied subjects in geology are capable of clearer and more satisfactory discrimination. It is true that the youth of geological *science* should make us cautious, but on this point our march cannot be backward; research can never weaken the

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ther at the time of, or subsequent to their formation. The general statement above is not meant to exclude local, occasional, or even general catastrophes, which are not inconsistent with long intermediate periods of prevailing quiet.

proofs already obtained, but will undoubtedly add constantly to their number and value.

TERTIARY, DILUVIAL AND ALLUVIAL.

XXIII. *The loose superficial masses of clay, sand, gravel, loam, pebbles and some of the superficial rocks appear to have been the last in the series of regular depositions;*[*] *they are now included under the Tertiary and Diluvial and Alluvial,* properly so called.

The *tertiary* comprehends the most recent members of what was until within a few years, included under the *secondary*, and also the oldest members of the former *alluvial.*

The *diluvial* embraces what is conceived to belong to the deluge,[†] and the *alluvial* is now restricted to the deposits, chiefly mechanical, arising from agencies still in operation, and which have been always active, such as the weather, floods, rain, frost, electricity, &c. &c.

This threefold division has become necessary in consequence of the progress of discovery. The tertiary division sustains very nearly the same relation to the secondary, on the one hand, and the diluvial and alluvial on the other, as the transition does to the primitive and secondary. In either case, we may separate the subjects of the division referred to, and distribute the members between the two contiguous classes, but in both cases, a degree of confusion wlll be the result.

In colloquial language, it is not very important to distinguish between diluvial and alluvial. It may be sufficient, for the purposes of conversation, to speak of loose masses generally as alluvial; but in accurate geological discussions, it is important to distinguish between the effects of causes now in operation and of those which belong to catastrophes, of which the occurrence of the last is evinced, by the entire appearance of the surface of the earth, by the record of sacred history and the traditions, mythology, fables and poems of most heathen nations, ancient and modern, savage and civilized.*

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[*] Always excepting of course, the volcanic and ignigenous formations, which are irregular and obey no settled law of succession.

[†] Or deluges, for there may have been repeated *physical* events of this kind, more or less extensive, although there has been only one general vindictive one and only one general deluge since the creation of man.

It has been usual to speak of the great sandy, gravelly and clayey district of the southern American states, extending from the ocean to the high country, as alluvial; but in fact, a large part of it is tertiary and diluvial, and only a small part is strictly alluvial.

It is true, that in a scientific view, the production or preparation and transportation of the materials of the alluvial and diluvial, is due to the same general class of causes, but the scale of operations is widely different, and the diluvial are attributable to catastrophes, sudden, short, violent and occasional—the alluvial to causes comparatively or generally feeble, although sometimes violent, and always in operation.

XXIV. *In these looser superficial deposits, we find most of the remains of the larger and more perfect animals, and it is rare that trees*† *and their larger members are found in deposits of a more ancient date.* This epoch embraces the period of the very termination of the redemption of the earth from the first watery abyss.

It appears necessary here to remark that the last operations of the primitive ocean were, in all probability, similar to those of our present oceans. Indeed, had not the deluge supervened and introduced, along with these, a new set of effects, it might not perhaps have been possible to distinguish between the last operations of the first ocean and the daily effects of the present; or rather, the latter would, as far as we can understand, have been little else than a continuation of the former. Indeed, a certain part of the effects of the primitive ocean is liable to be confounded both with those of the present and of the diluvial ocean.

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* See an abstract of these facts in the Edingurgh Encyclopedia, article Deluge.

† Trees and their branches and roots are sometimes found in the coal formations in the sand stones, in the lias limestone, &c. which proves that the gigantic vegetables were sometimes embraced in the depositions that were formed in the later periods of the subsidence of the primitive ocean, as well as at epochs still more recent, some of which come down to our own time.

The discrimination is however not important, and these remarks are introduced merely to qualify the statements already made, respecting the general dissimilarity between the phenomena of these different periods.

The similar effects to which allusion is now made, are the general production of debris and wreck, but chiefly of rounded, water worn stones and bowlders.

There can be no doubt that these are now produced, or their forms modified by the moving waters of the surface of our planet.

No one who, on the sea shore, has observed the incessant lashing of the waves, and has listened to the hollow hum of the stones and pebbles rubbing against each other, with ceaseless friction, can doubt, that rounded, water worn pebbles are now every moment forming; and were they found no where else, except on the shores, and in moving waters, there would be no difficulty in assigning their origin generally to this cause. But rounded stones, water worn pebbles and bowlders are found, in every country, on the surface, and in the soil, and in regions the most remote from the ocean. This of course proves the universal prevalence of the waters.

Why not attribute the formation of the inland water worn stones to the *diluvial* ocean? The answer which must be returned is, that the time is too short for the process of grinding down, which would occupy a very long period. The deluge could, and evidently did transport and deposit immense masses of these ruins, where we now find them; but it was not possible that it could, in so limited a period, have effected much, in grinding down the angular fragments of quartz and of other hard stones, into ovoidal and globular pebbles, and bowlders. That effect appears to have been, principally, the work of the primitive ocean, which was not limited to a short time.

XXV. *Bones, single or connected, and even entire skeletons of the larger animals, (as the mammoth or mastodon, and other varieties of elephants, the rhinoceros, the hippopotamus, the tapir,* *elks,*[*] *deer, bears, horses, oxen, whales, &c.) are found abundantly in many countries, buried in the upper and looser strata.*

Trees and their members, and even entire forests are found in similar situations.

In general, the bones and trees are not mineralized, but are rather, for the most part, in the condition of grave bones or ancient wood.

The bones could not be found in the older strata, if the animals were not in existence when those strata were deposited. Much less could we expect to find human bones in these strata, for man, evidently, was not created till the earth was reduced to complete order, and many generations of animals and plants, had lived and died; depositing their remains in the rocks, whose formation was contemporaneous with the existence of the animals or plants, or immediately subsequent to it, or whose materials were accumulated, by catastrophes that also overwhelmed the organized beings.

Few or no gigantic animals, of any description, are found in the solid strata, below the lias[†] limestone. In that rock, and also in other strata, above and perhaps below, there have been found, within a few years, in England and elsewhere, gigantic oviparous animals of the saurian or lizard family: their remains indicate animals of twenty, forty, fifty, and seventy feet or more in length.[‡] They were amphibious, and there is every reason to believe, that when only the mountains and higher hills of England, were redeemed from water, and stood out as islands, these enormous animals, closely allied to the crocodile and alligator, that is to say, being of the same genus, but of different species, swam and sported about, in the inter-insular waters of primitive Britain.

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[*] The cervus megaceros (Irish elk,) is probably extinct, and perhaps some other cotemporary species.

[†] A local name, used in England. The hydraulic lime of New York, is a lias.

[‡] In the interesting collection of G. W. Featherstonhaugh, Esq. in New York, there is a fine head of one of these ancient animals, and a very instructive series of specimens, illustrating the history of the bones found in the caverns, and in the diluvial formations of England.

Probably no land quadrupeds are found in any formation earlier than the tertiary.*

This is easily understood. Until this period, there was not dry land enough for terrestrial quadrupeds. It was evidently a period more advanced, than that which produced the ancient crocodiles; more land was uncovered, but a multitude of natural basins were still full of water, forming lakes, and as the strata which they now present, were in the course of being deposited, various quadrupeds, fortuitously conveyed into the water, or perhaps drowned by accident or by partial inundations, became solidified, and their remains are now found in the basins of Paris and London, and of the Isle of Wight. In general, their bones are not mineralized, or but partially so, and rarely are they perfectly changed. They are also much less frequent, than the marine animal remains of the earlier strata, probably, both because the animals were much less numerous, and because the circumstances attending their existence and death, were far less favorable to their inhumation.

It is worthy of remark also, that in the very strata in which they are contained, the relics of water-born animals are very numerous. It is believed, by Cuvier and Brongniart, whose elaborate investigation of the Paris strata, has been several years before the world, that there were successive periods, in which the waters produced, alternately and successively, marine and fresh-water shells, but perhaps our acquaintance with these ancient animals, does not enable us to decide positively on this point.

The most remarkable of the solid strata of the tertiary, are the *calcaire grossier* of the French, millstone, sandstones and gypsum; and among the materials that are not solidified, numerous beds of clay, marle and sand.

The tertiary formations having been distinguished only within a few years, have, as yet, been only partially examined, and almost exclusively, in France and England. There can be no doubt, as already observed, that much of the great alluvial, as it has been called, of the United States, is really tertiary.* The tertiary passes into the diluvial and alluvial, by almost imperceptible shades, and as it is not easy, perhaps it is not important, to draw the line of separation with perfect accuracy.

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* See a remarkable fact—American Journal of Science, Vol. II. p. 146.

It has been generally admitted, that no viviparous quadrupeds, nor any vertebrated animals,† except amphibious ones, are found lower down than the chalk. Professor Buckland, has, however, discovered in the Stonesfield slate, near Oxford, the bones of birds‡ and of a species of opossum. Few large terrestrial quadrupeds are found in the strata beneath the diluvial and alluvial.

Of course these could not exist, in any great numbers, until the land was chiefly uncovered, and their inhumation is, we presume, to be ascribed, with few exceptions, to the deluge of Noah.

XXVI. *Many revolutions more or less extensive, the result of earthquakes, volcanos, tempests and even deluges, partial or general, and perhaps of other causes, now unknown, may have preceded the formation of man.* Of these revolutions, there is abundant evidence in the strata, which as already stated, are often contorted, elevated, depressed, dislocated and blended, and the same relics are asserted to be found in the strata of the same kind repeated at different depths, and separated by other intervening beds of rocks, containing also in many instances, their own peculiar remains. These facts if established by sufficient evidence, prove the existence of successive generations of these beings and their submersion and inhumation by the alternate and successive prevalence of the waters.

There is every reason to believe that the creation of animals and plants was successive; not by equivocal generation—not by atomic action, but by the fiat of the Almighty.

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* See two excellent papers on this subject, by Prof. Vanuxem and Dr. Morton, in the Journal of the Academy of Natural Sciences of Philadelphia, Vol. VI.

† For a notice of a vertebrated animal five feet long, found in old red sandstone, see American Journal, Vol. II. p. 146 and Vol. III. p. 247.

‡ Birds are supposed to have been found in the English lias.

The waters, at different periods, appear to have been adapted to the support of different races, and therefore, their remains were successively solidified. When this happened, it is not necessary to suppose that the animals of a particular race were all extinguished; a multitude of them were entombed, as is proved by their remains; but individuals probably survived, in sufficient numbers to continue the respective species; in the mean time, other animals were created, and new races were petrified in the forming rocks: again perhaps the diminished race prevailed anew, and becoming again the tenants of the waters, presented their relics to be solidified in a new deposition, and so on in succession.

As to plants, it has been already remarked that their relics (the coal formations excepted,) are far less numerous than those of animals. It is in no way surprising that their creation should have been successive, and associated with different rock formations, and if the same plants occur in successive repetitions of the same or of different formations, their seeds or roots might have been preserved in the waters or transported from other places.

It is in no way inconsistent with natural laws, that the particular state of things which attended a particular rocky deposition, should have been such also, when the same kind of rock came to be deposited again, as to favor the production of the same animal or vegetable races from the germs, seeds, roots or individuals that had been preserved. The temperature of the great waters under the same circumstances, is liable to little variation, which would greatly favor a similarity or identity of productions.

In the same latitudes there is now, on the earth, a great regularity in the vegetable species, and, in a less rigorous degree, in the animal races.

But the geologist is not obliged to remove or to solve every difficulty, however gratifying it may be to effect this object. His first duty is to ascertain correctly, and to describe faithfully, the great facts, and if they are inexplicable it is not his fault. Every thing in nature will not have been explained till time is no more.

In the present case however, we are quite sure that these interesting relics are not referrible to the deluge; that short, transient and violent catastrophe; and it is wholly incredible and inadmissible, that the plants and animals were made in the rocks. They are not a lusus naturæ, and no solution presents itself to the writer, but the one that has been given.

XXVII. *In most of the earlier strata that have been described, the animal remains are mineralized or petrified,* that is they are changed into rock or stone or other mineral matter, or at least enclosed in it; they form part of the solid strata; they are found at great depths, with vast piles of strata, and mountains, often of different kinds of rocks, lying over them; they extend in many instances, hundreds of miles in continuity; their number exceeds all estimation; and for all these reasons it is obvious, that their deposition and that of the rocks in which they are found must have occupied a great length of time.

The creation of the planet was no doubt instantaneous, as regards the materials, but the arrangement, at least of the crust, appears to have been gradual. As a subject either of moral or physical contemplation, we can say nothing better, than that it was the good pleasure of God that this world should be called into existence; but, it seems also to have been his pleasure, that the arrangement, by which it was to become a fit habitation for man, was to be progressive.*

This is in strict analogy with the common course of things in the physical, moral and intellectual world. The human mind, the bodily powers, the inception and growth of the animal and vegetable races, the seasons, seed time and harvest, science and arts, wealth, civilization, national power and character, and a thousand things more, evince, that progression is stamped upon almost every thing, and that most things reach perfection, not by a single leap, but rather by a slow, although sure course.

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* It is a most remarkable fact, that every great feature in the structure of the planet, corresponds with the *order of the events* narrated in sacred history.

The gradual preparation of this planet for its ultimate destination presents therefore no anomaly, and need not excite our surprise.

THE DELUGE AND DILUVIAL ACTION.

XXVIII. *There is decisive evidence that not further back than a few thousand years, an universal deluge* swept the surface of this globe, and produced certain alterations in its physiognomy.*

SUGGESTIONS AS TO A POSSIBLE PHYSICAL CAUSE.

As the immediate cause of the deluge was the will of the deity, it is not necessary to prove that he who created the planet, and covered it with the primitive abyss, could again bring over it a world of waters.

In a moral view then, it is sufficient to say that it was the ordinance of heaven.

But as God, although able to effect the object by the fiat of his command alone, usually works by means, it is very proper to enquire if there are any natural powers which might be employed to deluge the earth.

The rain of heaven is mentioned as having descended for forty days and forty nights, and the fountains of the great deep are stated to have been broken up. It seems necessary therefore to infer, not only that a deluge descended from the atmosphere, but that it burst forth with violence, from the bowels of the earth. In a physical view, such an event would seem to be indispensable, as the atmosphere could discharge only the waters that had ascended into it, by evaporation, unless we imagine that water was created for the purpose in the atmosphere, or brought into it from other regions, either of which would be miraculous.

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* The deluge of Noah as already stated, was however, totally distinct in its effects, from those which we have attributed to the primeval waters of the great abyss, except, that there may have been some similarity near the termination of the primitive deluge, when its waters would most abound with mechanical effects and deposits.

Although the scriptures are not to be regarded as a text book in physics, their allusion to the rupture of the fountains of the great deep seems not to be made without meaning.

When referring to the retiring of the first or primitive ocean, a suggestion was made as to the possibility of the existence of caverns in the bowels of the earth. It is true the fact cannot be proved, but in a sphere of eight thousand miles in diameter, it would appear in no way extraordinary, that many cavities may exist, which collectively, or even singly, may well contain much more than all our oceans, seas, and other superficial waters, none of which are probably more than a few miles in depth. If these cavities communicate in any manner with the ocean, and are (as if they exist at all, they probably are,) filled with water, there exist, we conceive, agents sufficiently powerful to expel the water of these cavities, and thus to deluge, at any time the dry land. These agents are the *aerial fluids*, *the vapors and the gases*—whose competency to any and every degree of energy, which a given mechanical movement may require, is abundantly exhibited, in the rending force of gun-powder, and of the other still more potent explosive chemical compositions, and in the phenomena of earthquakes and volcanos, whose mechanical effects, depend principally, upon the sudden and abundant evolution and great expansion, by heat, of aerial bodies. These bodies, suddenly evolved, (especially steam at a high temperature,) and subjected to pressure and resistance, are sufficient, not merely to propel cannon balls and bombs, to burst rocks and to explode mines—they can rend mountains—they can shake them from their bases—and cause continents and the globe itself to vibrate and tremble.

If then, there were occasion to elevate a column of water even six miles in height, above the present ocean level, so that it should transcend the highest mountains; aerial fluids, aided by internal heat, would be equal to the effort. Should they be disengaged, abundantly, in the vast subterraneous and subaqueous cavities, they would, of course, occupy the roof or vaults, and would therefore expel the water, which we suppose they may contain, and this water rising, and spreading itself over the dry land, might submerge the continents, more or less completely. In short, if heat were concerned, it would be merely a case of steam or compressed air, acting to raise a column of water, as in a fire-engine. If it be objected, that the pressure would split the incumbent earth, we answer that it would do so did not its counteracting pressure, arising from a specific gravity at least two or three times greater than of water,[*] resist, with even superfluous energy, and the overflowing water would add to the pressure.

It will be found that to cover the highest mountains, existing at this time upon the earth, no more water would be required than is sufficient to occupy a cavity whose cubical contents are equal to about $\frac{1}{265}$ part of those of the globe. If the cavity were in the centre and were all in one, its diameter would be nearly one thousand two hundred and seventy-seven miles, extending six hundred and thirty-eight and a half miles each side of the centre, and of course leaving over three thousand three hundred miles for the thickness of the containing shell.[†]

If the void space were distributed in various parts of the globe, of course the thickness of the walls must depend upon the proximity to the surface; but, a few leagues or perhaps miles of thickness would be sufficient to give the strength, requisite, to resist the pressure.

A force five times as great as that used with safety by Mr. Perkins, in his celebrated experiments with his generator, would raise a column of water, and of course an ocean, higher than the top of the Himmaleh mountains.[‡]

If volcanic or internal heat in the earth should create steam, sufficiently abundant and elastic, to sustain this enormous pressure, would it not throw the whole ocean into ebullition? It would cause the parts contiguous to the fire to become red hot, and to assume the elastic form, or there would be no power generated, but water is so bad a conductor of heat that the ocean surrounding the globe, and at a distance from the internal heated cavities, might remain cold. A similar course of reasoning, will apply to the extrication of gas.

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[*] Possibly even much greater, according to the deductions of Maskelyne and Hutton on the specific gravity of the earth.

[†] Private communication to the author.

[‡] Measuring from the surface of the present ocean.

How would such an ocean elevated by aerial agency, ever descend? By condensation of the steam and absorption of the gas, on the cessation of the heat.

Would not gas, and much more vapor, under a pressure of perhaps many miles of water be of course condensed by the force,* or be prevented from ever becoming aeriform? It would if cold, but igneous agency has no known limits and would, in a given degree of intensity, counteract and overcome the condensing effects of pressure.

Would not gas or vapor, as the earth revolved, escape, by blowing out of the orifice, connecting the cavity with the surface? It would do so, if the channel had a particular direction in relation to the axis of the earth, but if parallel, and still more if tortuous, (which corresponds with what we know of the inlets to caverns,) the contained aerial matter or most of it would remain imprisoned. It is not pretended that the method here sketched was the one actually employed; it is sufficient for the present purpose to shew that it is physically possible.

Have we any case of analogous facts, which may redeem our supposition from the appearance of hypothesis, invented for the occasion? We have such a case: it is that of volcanic eruption. According to Humboldt, lava sometimes issues, at an elevation of eighteen thousand feet.† As we are wishing to apply a measure to the supposed power, we will take this extreme case, for the very reason, that it shews the extent of the power, (not its extent in possibility, but as far as it has been hitherto ascertained.)

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* As Mr. Faraday has shown that many of the gases are actually condensed by the conjoined effects of pressure and cold.

† The volcanic mountains in Hawaii, (Owhyhee.) Mouna Roa and Mouna Kea, each estimated to be over eighteen thousand feet high, evince that this statement is not exaggerated.—*Am. Jour. Vol.* II. *pa.* 2. Cotopaxi is another example.

Melted lava, especially under the pressure of so many thousand feet of its own fluid substance, may be estimated to have the specific gravity of at least 3. water being 1. Consequently, a power which could raise lava eighteen thousand feet, would raise water fifty-four thousand; this would cover the Himmaleh mountains, and leave twenty-eight thousand feet, (about five miles and a third,) for the depth, from the surface of the earth, of the cavity where the power might be exerted.

But this is not all. It is incredible that such volcanic mountains as Mouna Kea and Mouna Roa in Owhyee, eighteen thousand feet or more high; Teneriffe twelve thousand five hundred; Cotopaxi twenty thousand, three hundred and twenty feet, all raised by volcanic eruptions, could have the laboratory, from which the power and the lava issue, at a smaller depth under the surface, than that by which these mountain rise above it. With any thickness of roof less than this, the whole covering must be blown to atoms, by the tremendous effort which raises the lava.

Take here again the extreme case, Cotopaxi twenty thousand, three hundred and twenty feet high: lava of sp. gr. 3. raised to this height, would imply a power, that would raise water sixty thousand, nine hundred and sixty feet, measuring only from the level of the sea; but, if the cavern, from which the lava issues, is as deep in the earth as the mountain is high above it, the power exerted would raise water one hundred and twenty-one thousand, nine hundred and twenty feet, or between twenty-one and twenty-two miles. It will be observed, that the power which as we *know*, actually raises the lava, is the same, that we suppose, may be employed to raise the water, and this power is actually exerted in caverns deep seated in the earth, for it is incredible that a mountain that has itself been raised by volcanic eruptions, and whose entire substance is congealed lava, should contain the cavities from which floods of lava are still made to flow, age after age, for the mountain would explode with its own throes and convulsions, as that of Sumbawa in the island of Timor, did, not many years since. We have proved therefore, that there are caverns in the earth, where igneous agency is exerted, and sufficient power is generated, to raise all the water that would be required to deluge the mountains.

Still, we do not affirm that this was actually the *modus operandi;* but merely, that the hypothesis is consistent with physical laws, because the very case which we have supposed, is a frequent occurrence, only the fluid raised is molten rock, instead of water.

We forbear to push our supposition to the extreme, by shewing that it is probable, that volcanic cavities are often much deeper than we have stated—otherwise, the volcanic mountains might be in danger of falling in, as the ancient dome of Kirauea probably has done; and it is very difficult otherwise to conceive, how volcanos communicate with each other under ground, and how the earthquakes which they generate, are transmitted even to other continents.

We forbear from stating other hypotheses which have been or might be suggested; such as that of the approximation of a comet, or of other foreign planetary influence.

XXIX. *The deluge of Noah was an exterminating and punitive infliction; sudden in its occurrence, short in its duration, and violent in its effects.*

The immense, and universally diffused masses of sand, clay, loam, gravel, pebbles, bowlder stones, inhumed wood and forests, bones and skeletons of gigantic, as well as of smaller animals, and the vast cemeteries of animal remains discovered in caverns, owe their preservation, and generally, (except the last, viz. the bones in caverns,) their present position, to the overwhelming destruction of this mighty debacle. Professor Buckland, in his Reliquiæ Diluvianæ, has most ably illustrated this subject; and it is obvious, that the former practice, of attributing the organized remains found in the solid strata, to this catastrophe, is founded entirely in an imperfect acquaintance with the subject, and that no man, at the present period, who had studied geology thoroughly, would fall into such an error.

That the diluvial ocean was equal to all the violent effects now attributed to it, can, we think, be proved, by a little attention to the circumstances of the phenomenon.

In stating these, I shall take it for granted, that the Mosaic account of the event, is true. I would remind the mere geologist, that the evidence of probable history, is always admitted in the statement and discussion of geological facts. In the present instance, the history, without taking into view its divine origin, bears every mark of verisimilitude. It is simple and perspicuous, and it is also probable; because it corresponds with the appearances upon the surface of the earth. We need not the history, in order to prove the occurrence of an universal deluge. This is sufficiently proved, by the vestiges left upon the globe, and geologists are generally agreed in admitting the fact.

The only point, for the establishment of which we need to advert to the history, is the time which the catastrophe occupied, and particularly, the great divisions of this time, by the ascent, the continuance, and the decline of the waters.

Another preliminary to the statements which are to follow, is, that the mountain ranges were the same at the time of the deluge as now, except that they are not so elevated. That an universal deluge has occurred, since the earth was peopled by human beings, is stated in a credible* history, namely, the Mosaic; the traditions, history, mythology and poetry of all nations, contain allusions to the same event; and it being distinctly stated in the Scriptures, and implied in most of the other sources of information just alluded to, that its object was punitive, it of course follows, that it happened since the completion of the series of geological events, which fitted the earth for the reception of man. The mountains, being a part of the "great frame work" of the globe, may reasonably be supposed to have existed before the deluge; since, whatever may have been the proximate physical causes of that event, there is no reason to believe, that on that occasion, continents sunk, or were born from the womb of the deep; but on the contrary, there is positive geological evidence, that the mountain's ranges are the same as before the deluge.

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* We speak of it as *credible*, because it corresponds with *physical appearances*; this being the point, essential to the *geological* argument.

Every thing in the lucid and graphic history of the bible, leads to the conclusion, that the waters rose till the land was submerged, and not that the continents subsided into the bosom of the earth. If they did subside, it must have been all hollow beneath them before; but granting that they sunk into cavities, what power raised the new continents,* or before sustained the old?

RISE OF THE WATERS.

Taking it for granted, that the antediluvian mountains were the same as the present, but somewhat higher, and that agreeably

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* Mr. Penn, in his Comparative Estimate of the Mineral and Mosaic Geologies, (second edition,) has stated it as his opiuion, that the waters of the primitive abyss retired into superficial cavities scooped out for them, by the breaking up and sinking of the crust of the earth, or of as much of it as was necessary for that purpose; thus forming the bed of the ocean and seas, but, as he supposes the primitive ocean to have been withdrawn in the course of a few days, and maintains that there was no such thing as *formation* or progress in the deposition of the primitive rocks, but that all their crystals and other constituent parts were created at once, as we now see them, no reason appears why the planet was submersed at all, and certainly none why the great waters were so rapidly withdrawn. Mr. Penn, although strenuously opposed to the admission of any more time before the creation of man than what is commonly allowed, is still so much impressed with the utter impossibility of attributing the mineralized organic remains and the fragmentary rocks of the globe to the transient catastrophe of the deluge, that he resorts to a supposition which appears quite original.

Believing the organized remains to have been produced and petrified in the bosom of the oceans and seas, as they existed between the creation of man and the deluge, occupying a space of 1656 years, he supposes that when the deluge came, the then existing continents were also broken up and plunged into the bowels of the globe, and not only so, but that cavities were formed over these sunken continents so deep that the seas and oceans were drained off from their former beds, running by subsidence into these new cavities, and thus disclosing the bottom of the former seas and oceans, which form the continents of our present habitable world.

As this theory supposes, in order to provide for the withdrawing of the two oceans, namely, the primitive and the diluvial, that, first and last, the entire crust of the planet, both the dry land and the submarine must have been broken up and sunk, we are of course led to enquire, whether there was a general cavity beneath the entire crust of the planet, (as a little globe is sometimes, in our artificial apparatus, supported within the encircling rings of an armillary sphere, or like a nut loose in its shell, or as the loose kernel (noyau) often included in the argillaceous iron ore, called œtite.)

to the scripture history, they were all covered; we have the measure of the altitude of the flood; and from the same history, we learn also the time in which it rose.

Supposing that the highest elevation was five and a half miles; as it was forty days in rising, it rose nearly at the following rate, that is, a foot in two minutes, thirty feet in an hour, one hundred and eighty-one feet in the time of a common flood or ebb tide, three hundred and sixty-two feet in the entire time of the flux and reflux of a tide, and seven hundred and twenty-six feet in twenty four hours. This is upon the supposition that the waters rose upon the surface

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If there were such a cavity what filled it before the subsidence? What sustained the encircling hollow sphere in its place? If there were no such cavities how could the continents sink? If the cavities were formed at the time by convulsions, what became of the displaced materials?

But, it is not necessary to pursue these enquiries; for, the discoveries of Prof. Buckland, as to the antediluvian caves, have proved, that the continents that now exist above water, are the same that were inhabited before the flood. The caverns that were then tenanted by hyenas, bears, and other wild animals, as their dens, present innumerable specimens of their remains, and of those of the animals, or parts of animals, which they dragged in for food, or which sought in these places a refuge from the common danger; and these remains are covered by the diluvial sediment, which was floated into them, when the waters were turbid with the suspended mud, and thus these apparently trifling relics have been preserved to the present day, as memorials of that great event.

It is impossible to give, on this occasion, even an abstract of the details by which these indications are established.*

A diligent attention to the facts of the same class that have been discovered since the publication of the Reliquiæ; a very careful re-perusal of that work for the second and third time, after a full consideration of the objections of those two very acute writers, Mr. Penn, an able critic, and of Dr. Fleming, an accomplished naturalist, have left on the mind of the writer a conviction, in no degree impaired, that Professor Buckland's opinions respecting the identity of the *ante* and *post* diluvian continents are sound and correct. We have been delighted with Dr. Fleming's notices of the history of the animal races in Britain and elsewhere, but we still believe that the caverns were antediluvian, and of course, that the continents were not sunk on that occasion, but drowned and ravaged in situ.

Any thing rather than conviction was produced by the effort of Mr Penn to account for limestone caves and their diluvial bones, by the strange imagination, that the supposed calcareous paste of the deluge had been blown up into caverns by the

* For an able analysis of this work by Prof. Hitchcock, see Am. Jour. Vol. VIII. pp. 150 and 317.

of a regular sphere, in which case, they would rise in vast ridgy waves, presenting, every where, much the same appearance and effects. But as the hills and mountains, over the entire surface of the land, would oppose barriers to the rise of the water, the rapidity of the tides would be much increased, and in many situations, the water would rise with redoubled force, and every where overflow the land with increased rapidity.

In order to appreciate, justly, the effect of such a tremendous rush of waters, we must compare it not only with common tides, but with those more violent ones with which we are acquainted.

" Between Matacapa and the North Cape, in the place where the great canal of the river Amazon is most confined by the islands, the tide presents a singular phenomenon. During the three

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gases evolved during the "*immense*" putrefaction of the drowned and transported elephants and other animals, involved in that paste, and inflating it by the gases produced during their decomposition, and that thus these extraordinary excavations were formed.

What blew up the stupendous caverns of Kentucky* and other western and south western American states, extending for miles into the earth, and containing no bones except a few inhumed skeletons of the aboriginal Indians? Why is there no *inflation*, around the bodies of fishes and of larger animals whose remains are found in limestone and other rocks?

We decline however to follow this subject, and while we acknowledge with much satisfaction, the instruction derived from the *study* of *both* Mr. Penn's editions of his learned, elegant and very interesting work, we must be permitted to say, that none of the geological theories which he has so ably combated, appear more extravagant than the two to which we have adverted, and no writer on geology who professes to be a believer in the scriptures, has taken that liberty with the history, which Mr. Penn has done, who does not hesitate to pronounce the four verses which mention the rivers issuing from paradise, to be marginal interpolations, because they describe the then existing rivers as being the same that flowed there before the deluge.

To a writer of such high moral tone, and great mental power and acquirements as Mr. Penn, we would not speak in the magisterial manner, which, very prominent in his first edition, but softened in his second, would leave him in such case, little cause to complain.

But his work, searching as it is, has served the cause of truth, and we feel obliged to him for its publication, although he has, in our opinion, left the question between the critics and the geologists embarrassed with all its difficulties.

* The mammoth cave of Kentucky has been explored for ten miles, without finding an end; these caves are in the ancient secondary or transition limestone.

days nearest the full and new moons, (the times of the high tides,) the sea, instead of employing nearly six hours to rise, attains its highest elevation in the space of one or two minutes. It may be supposed, that this is not effected very quietly: a terrific noise is heard, at the distance of one or two leagues, which announces the pororoca, (barre or bore;) such is the name which the Indians of the district, give to this terrible tide. In proportion as it advances, the noise increases, and presently, one beholds a promontory of water, from twelve to fifteen feet in height; then a second, then a third and often a fourth; which follow close upon each other, and which occupy the whole breadth of the canal. This surge advances with a prodigious rapidity, breaking down and shaving clean away, every thing that opposes it. I have, in some places seen an extensive tract of soil carried away by the pororoca, trees of very large dimensions uprooted, and devastations of every description. Wherever it passes, the coast is laid as smooth as if it had been intentionally and carefully swept."*

Mr. Penn mentions also, the following fact, which he says, was obtained from an eye-witness.

"At the mouth of a river in Nova Scotia, a schooner of thirty two tons, laden with live stock, was lying with her side to the tide; at the influx of the Bore; which was then about ten feet in perpendicular height. No sooner had this mass of water reached the vessel, than that great body was instantly turned over, like a barrel and presently disappeared. After the tide had ebbed the schooner was so totally absorbed into the sand, that the taffel or upper rail of the deck, was alone visible."

This account corresponds with the the common statements, respecting the tides in the bay of Fundy, which are said to rise sixty feet, to come roaring in like a mighty rushing flood, and that people and animals upon the beach sometimes, with difficulty escape with their lives.

Similar facts are observed in the river Mersey, at Liverpool, and in the Frome, a branch of the Severn, at Bristol, in England, where the tides rise between twenty and thirty feet, rushing in, through the channels, in a tumultuous torrent, which requires peculiar precautions, to guard against its effects.

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* Condamine's Voyage, quoted by Penn, Vol. II. p. 100.

There are tides in England, of sixty or seventy feet in height. The following notice of such a tide and of some other interesting circumstances, connected with the flow, of water, was communicated to me, by a gentleman from Georgia, who had travelled in England.

"The two principal branches of the river Wye, take their rise in Hereford, and Montgomery Shires, and unite their waters, at Monmouth, from whence to the Severn where it empties, the Wye is navigable. But vessels with masts, never ascend beyond Chepstow, which is situated in Monmouthshire. The country through which this river runs, being of mountainous character, its stream is consequently much broken by rapids, and cataracts, and as it approaches Chepstow, it becomes much more narrow, being confined on either side by precipitous and rocky sides. At Chepstow, the river makes a sudden curve, the town occupying the convex side of the river. The strength of the stream presses against the Gloucester bank, and an eddy is formed on the side of the town, by which vast depositions of mud and sand are made. But these encroachments, are often swept away by the rapid and overwhelming floods that are occasionally poured into the river, through the ravines under the Welsh mountains. I was in Chepstow in 1820. Immediately previous to my arrival at that place, there had been many successive days of rain, and the tide was said to have risen sixty feet on that occasion! and I was informed by the inhabitants that it had been higher. I saw many vessels in the stream secured by cables made fast to capstans on each side of the river. The rapidity of the receding tide was so great, that the water was running two or three feet over the decks of some of the vessels, while others which had not been sufficiently secured against leakage, were sunk; and it frequently happens that after rainy seasons, vessels are unable either to receive, or deliver cargoes until the mountains have "dried their cheeks." The old bridge across the Wye, which was swept away and rebuilt many times during the last century was finally annihilated, by a freshet which happened sometime in 1813 or 1814. It stood on wooden piers, raised more than forty feet from the bank of the river. The present iron bridge is erected on stone piers, of nearly fifty feet from the bank, and notwithstanding the immense piers of rock and stone, (based in the bed of the river) which support its middle arches, the vibration occasioned by heavy floods is so great, that it is considered dangerous to pass it at such seasons, as the most gentle horses frequently take fright and do much damage, when they find themselves on so unfirm a foundation.—I was told by an intelligent old gentleman of the town, that of late the water has frequently risen much higher than it did when he was a boy, which circumstance was attributed to the great agricultural improvements, which had taken place on the bank of this river, and particularly in draining, as the water, by those means, was more suddenly conveyed into the stream.

"My old acquaintance also showed me a well, situated in a garden about three hundred yards from the river, whose water ebbed and flowed, (as regularly as the river) fourteen feet perpendicular. A little before the tide had attained its height, the water in the well began to recede; at high water the well was dry, and shortly after the river began to ebb, the water of the well returned.—The regularity of this routine was more affected by wet than dry weather."*

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* We had occasion, under the head of land slips and slides, p. 20, to mention those of the White mountains, and they were cited also as instances of diluvial action.

We now add a notice of a slide in the mountains of Vermont, in illustration of the same subject.

It happened in Lincoln, Addison county, on the 27th of June, 1827, in the forenoon. The slide commenced near the top of the mountain, between two large rocks which were stripped of earth, opening a passage of four rods wide, from which it proceeded in a south easterly direction, gradually widening for the distance of two hundred rods, to the south branch of Mill Brook in Fayston. In its course it swept every thing in its way; overturning trees, divesting them of their roots, branches and bark, and often breaking them into short pieces. A number of rocks weighing from fifteen to twenty tons were moved some distance. From where it entered

It is obvious that these facts are cited, in order to give us some standard views by which we may estimate the force of great moving waters, especially when their power is increased by lateral pressure, operating to narrow the channels in which they flow.

Every great rain gives us similar evidence, by the effects of the torrents which it creates, or greatly augments. They produce frightful devastation in their course, and sometimes bear before them every thing but the firmly fixed mountain rocks.

It would not be easy to cite a more striking instance of diluvial ravages, than those produced by the eruptions of Long Lake into Mud Lake, in Vermont, June 6, 1810,* on which occasion, earth, stones, large rocks, trees and forests, animals, mills, and other structures, were borne away with resistless impetuosity, with the noise of loud thunder, and the concussion of an earthquake—excavating the small outlet of the lakes, called Barton river, into a channel, sometimes one-eighth of a mile wide, and sixty or eighty feet deep—the devastation extending fourteen miles in length, and, to a degree, twenty two miles, quite to Lake Memphremagog.

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* American Journal, Vol. XI. p. 39.

Mill Brook, its course was in a north easterly direction, two hundred and eighty rods, the natural course of the brook being very small; but the channel cut by this torrent is now from two to ten rods in width; and on either side are large quantities of flood wood piled up very high; and from fifteen to twenty rods of the lower part it is blocked up across the channel in every direction; some of the trees are standing on their tops, and generally stripped of roots, branches and bark, and broken into many pieces. A large birch tree, measuring three feet nine inches, was broken off square. A black ash was literally pounded into a broom, whose brush is seven feet long. The force of the water was very great; in some places, it must have been thirty feet deep. Some of the trees on the sides of the channel were barked thirty or forty feet high, and there was mud on them at that height.

The report was heard at the distance of several miles, and by some was thought to be an earthquake—by others, a clap of thunder, but unaccountably prolonged and attended by a perceptible, continued jar. Fortunately, as it was a number of miles distant from any human abode, wild beasts alone, were exposed to its ravages.*

In its whole course before reaching Mill Brook, it swept through a dense forest, mostly of hemlock and spruce, and took off the entire surface, and every thing which it contained. The ground appeared to be as free from roots as if it had been tilled for fifty years. Some trees which were so firmly rooted in the rocks, that they could not be drawn out, were pounded off upon a level with the surface of the ground, as if they had been but slender reeds. At some distance above the stream the mass parted, and left a few rods square of timber standing—but soon united again—and rushing on in all its tremendous power, struck obliquely against the opposite bank of Mill Brook, with a concussion that shook the mountains. When-

* A similar occurrence took place a few years since upon the same peak, but on a much smaller scale.

The effects of the great storm of July 26, 1819, in the Cattskill range;* and those of the tempest in the White mountains,† in New Hampshire, August, 1826, by which the great slides in the notch were produced, will afford us additional evidence of the tremendous power of great moving waters.

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* American Journal, Vol. IV. p. 125. † Already cited p. 20 of this sketch.

ever a check was given to its progress, the torrent soon accumulated force sufficient to burst every barrier—and again the huge pile proceeded, thundering down the mountain. The forest seems to have been prostrated with as much ease as if it had been but a field of grain. The mass evidently went down in the wildest confusion. The trees sometimes erect, or sweeping around in circles, struck those upon the banks of the stream—as appeared by the bark frequently taken off at a great height—now their tops and roots, alternately projecting forward, and again lying across the current, were shivered in an instant. They are left in considerable numbers throughout the whole course, some lying upon the banks, others in the channel, and wholly or in part, buried in the sand and rocks. But the principal part of the timber swept from twenty-five acres of forest, now converted into a barren waste, lies piled in a confused heap, covering perhaps an acre of ground, one mile and a half from the spot where the slide commenced! Here, having already spent much of its force, and the mountain growing less precipitous, it struck into a cluster of firmly rooted trees and was compelled to stop. At this place it presents a perpendicular wall of logs, &c. across the entire channel, in some places ten or fifteen feet high. The upper end of the pile is buried beneath the sand and stones, and the stream now runs over the top. Perhaps those very logs will be dug out in after times as fossil wood.

Every thing in this mass, bears the marks of the greatest violence. Almost every tree is completely divested of its roots, branches, and bark, as could have been effected by man, with the proper instruments. They are pounded and splintered and broken into all imaginable shapes and lengths. The scene is well worth the attention of all who have never witnessed the effects produced by the agency of rushing torrents of water. No one who has contemplated such scenes, can doubt, that water is adequate to the production of any of these effects, which are ascribed to the deluge.—Cited from Mr. Baldwin's statement, American Journal, Vol. XV. p. 228.

The following fact is cited by Mr. Penn, (Vol. I. p. 50, Introd.) "On the 14th of October, 1822, a wave, which, during a storm, broke against the pier of Ramsgate, and was dashed upwards to a height of about fourteen feet, fell again upon the stone pavement of the pier head; and, by the force of its reaction, instantaneously raised a thirty-six pound carronade, with its carriage, over a stone ledge, and precipitated it into the sea. The harbor men assured me; that it would have required the utmost efforts of twenty men, to effect the same operation."

In the great tempest of September, 1815, among many similar effects, which happened all along the shores of New England, a vast ridgy wave, raised by the hurricane, came suddenly, in an overwhelming deluge, upon the lower town of Providence, in Rhode Island, and, by its force, entire rows of houses, and stores, and ware-houses, were, in a few minutes, prostrated. Ships of three and four hundred tons, were thrown upon the wharves, knocking down large buildings by their momentum; some were carried into the town, thrusting their jib-booms in at the second and third stories of houses; others were lodged in the streets, and a number, and those some of the largest,* after carrying away a strong bridge, were driven through a bay, usually too shallow, even for small craft, and were thrown up, high and dry, upon a beach, where the salt water has never been since, and may, perhaps, never come again. Nothing would be easier than to swell the list of such events; but these are sufficient for our purpose.

If such effects are produced by torrents, and tides of limited extent, and short duration, the highest of which scarcely equals one third part of that of the diluvial tides, for the same time, and whose duration was not equal, in any instance, to $\frac{1}{100}$ part of that of the waters of the deluge—if such ravages were committed by the Pororoca of the Amazon, by the Bore of Nova Scotia, and by the tides of the English Wye, what must have been those of the forty days tide of the deluge!

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* Among them, the Ganges, formerly a sloop of war.

Granting the measure of time given in the history of the event, and that of the elevation afforded by the highest existing mountains, (both of which appear to be fair grounds of reasoning,) it is not easy to exalt the imagination to an adequate conception of the terrors of that awful catastrophe. The inconceivably violent torrents and cataracts, every where descending from the hills and mountains, and meeting a tide, rising at the rate of more than seven hundred feet in twenty-four hours—resisted and aggravated in force, wherever it encountered the land, and still more, the hills, and the mountain ridges; accompanied, also, we may presume, by other great instruments of almighty power—the tempest, the volcano, and the earthquake: but with, or without them—impelled with resistless violence—it must have swept over the surface, with a force vastly greater than any thing that we now know of the mightiest rushing waters. It evidently rolled every where over the various inequalities of land, in tremendous agitated billows; and where it was narrowed by ridges, and hills, and mountains, and thus forced through valleys and defiles, it must have presented innumerable raging torrents and cataracts, of awful height, force and magnitude, compared with which, even Niagara would be insignificant; and at that time stupendous rapids and cataracts necessarily existed, wherever the water pitched over barriers and precipices.*

PHYSICAL EFFECTS OF THE DELUGE.

Are there any appearances upon the surface of the planet, proving that it has been ravaged by a violent, sudden, and transient deluge? The answer is, that they are numerous and convincing.

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* However proper in a moral, it is not necessary in a geological view, to advert to the terrors of the animal creation—and still more, to the dismay and despair of the human race. The traditions of all nations, shew that an indelible impression has been made by the event. Painters and poets have drawn the most vivid and painfully sublime pictures of those overwhelming scenes: and to their graphic touches we leave the subject.

Nor do we think it incumbent on us to shew, that the ark was safe amid that mighty movement of waters. A broad flat vessel, probably without spars and rigging, deeply laden, might well stand the agitation of that ocean; and, if grounded, it would be but for a moment, as the rising flood would immediately lift the floating structure clear again.

The effects of the deluge were not forming, but destroying effects: they were mechanical, and not chemical. There is not the least reason to believe, that any solid rock was produced at that period, nor that any of the firmly imbedded and petrified organized remains belong to this epoch. The diluvial ocean was agitated by a mighty moving force, or it would never have attained its greatest elevation within forty days; it was turbid in the extreme, and filled with the wreck of the surface of the planet, with moving rocks, stones, gravel, earth, and coarse and fine sediment—and with extirpated and floating vegetables, and drowned animals.

Its various effects may be included under,

1. Disposition of mineral masses.
2. Of animal and vegetable.

1. Mineral diluvium.

The distinction between diluvium and alluvium has been already pointed out.

Diluvium is found every where. The almost universal deposits of rolled pebbles, and bowlders of rock, not only on the margin of the oceans, seas, lakes, and rivers; but their existence, often in enormous quantities, in situations quite removed from large waters; inland,—imbedded in high banks, or scattered, occasionally, in profusion, on the face of almost every region, and sometimes on the tops and declivities of mountains, as well as in the valleys between them; their entire difference, in many cases, from the rocks in the country where they lie—rounded masses, and pebbles of primitive rocks, being deposited in secondary and tertiary regions, and vice versa; these, and a multitude of similar facts, have ever struck us as being among the most interesting of geological occurrences, and as being very inadequately accounted for by former theories. Pebbles may, in given instances, be formed, (possibly,) by decomposition of the angular portions of a stone—by various chemical agencies, aiding those of a mechanical nature—but an immense number, and, in our view, much the *greater* number of pebbles, present unquestionable evidence of having been brought to their rounded form by friction.

The attrition of the common waters of the earth, and even that exerted during the comparatively short period, of the prevalence of the deluge of Noah, would do very little towards producing so mighty a result; and we must assign this operation to the more recent periods of the prevalence of the first ocean.

Diluvial formations have a wave-like or undulating appearance.

This we have often observed in the plain of New Haven, and in other regions of Connecticut and New England—exhibiting frequently, a delicacy óf flexion, in the layers of gravel and sand, which makes them appear as if they had, but a moment before, received their impulse and position from undulating water, and as if they had copied the very eddies and gyrations of the wave.

Bowlder stones,* consisting of fragments of primitive rocks, probably from north of the great lakes, are found abundantly on the secondary regions of Ohio and Kentucky; the fragments of the primitive Alps, on the Jura chain, (the lake of Geneva intervening;) the ruins of the Scandinavian mountains on the secondary and diluvial plains of Prussia and Northern Germany, (the Baltic being between,) and the fragments of the northern counties of England, cover the southern and middle regions.

In many cases, bowlders and pebbles can be traced to their native beds, and frequently they are strangers to the regions where they are found.

Deserts of sand, covering tracts more or less extensive, such as those in South Africa, and in the Zahara, stretching in a vast belt, from the Atlantic ocean to the desert of Lybia; the sandy plains of Arabia, Germany, and Russia—the great desert at the foot of the Rocky mountains, and all similar deposits, in situations where no existing causes could leave them, are, with great propriety, referred to the deluge.

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* The rock, in Horeb, that, being smitten by the rod, gave forth water, is, according to SHAW, a bowlder of granite.

The diluvial waters appear to have transported and arranged these masses, by sedimentary deposition, and that they had sufficient power to roll even bowlder stones and disjointed columns* to great distances, is sufficiently evident, from what we know of the energy of torrents in our own time.

Beds of sand, gravel, clay, loam, pebbles and bowlders are found to compose the loose materials of every country, and they invariably exhibit the appearance of deposition from water, sometimes tranquil, sometimes more or less agitated.

The effects of the devastation which every where marked the rise of the deluge, were in a considerable degree veiled, by the gradual depositions of sedimentary matter that took place during the decline of the waters. The history informs us that the waters rose forty days, prevailed one hundred and fifty days, and gradually retired during six months, thus affording a long period, of comparative tranquillity, for the arrangement of the universal sedimentary beds which we now see.

As at the termination of the first ocean, there must have been a multitude of local lakes, determined, by the basin shape, so often traced by contiguous hills and high grounds; in these, separate and independent deposits were doubtless going on, for a length of time, even after the earth began to be repeopled. Those lakes that had no permanent supply of water, would, of course be exhausted by soakage and by evaporation: others would burst their barriers, or gradually wear them down and renew the diluvial ravages, during their escape; while those only would be perennial, which were fed by streams or springs.

Many valleys of denudation, as they are called by Prof. Buckland, were probably produced by the deluge of Noah. Such valleys are conspicuously seen in the South of England: similar strata are found capping contiguous hills, projecting at their sides, and running beneath their foundations; a curve or hollow having been scooped out between, thus indicating the effects of great rushing torrents, attended perhaps by convulsions, that more or less, broke up the superficial strata.*

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* Such as the columns of trap, sometimes of enormous size, which are found scattered, up and down, through the great Connecticut valley, often at a great distance from their parent ridges. The most remarkable case in this range, is ten miles west of Hartford, on the Albany turnpike.—See Tour to Quebec.

It is not intended that all valleys were produced in this manner; many doubtless were thus formed, and many more were deepened and modified, but a multitude of them were probably among the original features of the planet, or produced by early convulsions.

What has been said of diluvium is not intended to exclude the idea of alluvium. This is forming at all times by the action of causes now in full operation, and many instances of great effects of this kind might be cited; as at the mouth of the Nile, of the Mississippi, and in many other embouchures, in bays or sea coasts, lake shores, &c. On this subject it is not necessary to enlarge.†

2. Animal and vegetable bodies covered by diluvium.

A. *Human Remains.*

Are there any remains of the human race covered by the diluvium? Until very recently, it has been confidently answered that none have been found. The human skeletons discovered in tufaceous limestone both in Gaudaloupe, (Phil. Trans. of Lond.,) and more recently in Brazil, (Phila. Trans.) being arranged in uniform order, parallel, sloping, and with their heads all one way, were doubtless deposited in this manner for burial.

Those at Gaudaloupe, being situated where the tide ebbs and flows over them, were evidently in a more elevated situation with respect to water when they were interred than now; and water has probably been the agent, by means of which, the tufaceous rock has been formed around them. The circumstances of those in Brazil indicate that water has stood over them also, but they are several miles from the present sea, and the peculiar arrangement and other circumstances of both deposits, indicate that the bodies were interred with the rights of sepulture, and of course that they cannot be diluvial relics. For our present purpose, it is not necessary to discuss these facts any farther.

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* See this subject ably investigated and illustrated in the Reliquiæ Diluvianæ.

† See Dr. H. H. Hayden's interesting geological essays.

If there be any human remains, hitherto ascertained, that may be referred to the diluvial catastrophe, they are, perhaps, those discovered in the cavern of Durfort, in France,* and in the quarries of Kosrutz, in Germany. It would appear possible, perhaps probable, that the human remains found in these situations, were deposited there by the deluge. Such discoveries may be, hereafter, multiplied. They should be received with caution; but they cannot fail to be acceptable, both to the friends of geology and of the early scripture history.

When it is considered, that, excepting straggling colonies, scattered here and there, in remoter countries, the human family, at the time of the deluge, had probably, not extended far beyond the neighborhood of the Euphrates, the Tigris and other vicinal Asiatic countries; that even those countries, may not have been, at that time, very populous; that many of the corpses may have been swept into the ocean, many more buried deep in diluvium or in accidental cavities and fissures; that those countries, being without curiosity and without science; and under an arbitrary and jealous government, there is little probability, that discoveries relating to the extirpated human family, would be made, or, if made accidentally, that the remains would be regarded, by the ignorant and incurious inhabitants, in any other light, than those found in burying grounds.

Under a different sway, it is not, perhaps, improbable, that diluvial human bones may hereafter be found in Asia; but under present circumstances, their absence does not operate, in any degree, against the reality of the deluge, attested as it is, by so many geological facts, as well as by the history.

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* Penn, Vol. II. p 394.

B. *Remains of Animals and Vegetables.*

These are very numerous and equally unquestionable.

We would by no means insist, that every skeleton and bone, found in diluvium, was buried there by the grand catastrophe. We are willing to allow a reasonable number, and all that can on probable evidence be thus referred, to mere accidents, and to diluvium or alluvium, of a more modern date than that of the deluge.*

Single bones, parts of skeletons, and entire skeletons of the larger animals, often of extinct species, but mostly of known genera, are found abundantly in the diluvium of all countries, where curiosity and intelligence exist.

Whales, sharks and other fishes; crocodiles and other amphibia; the mammoth or the extinct elephant; species of elephants, nearly or quite like those of modern times; the rhinoceros, the hippopotamus; hyenas, tigers, deer, horses; various species of the bovine family, and a multitude more, are found buried in the diluvium, at a greater or less depth; and in most instances, under circumstances indicating that they were buried by the same catastrophe, which destroyed them; namely, a sudden and violent deluge.

The interesting and instructive geological essays of Dr. H. H. Hayden, may be consulted, for a series of facts, relating to the diluvium of the Atlantic portion of the middle and southern states of North America. It appears, that under this diluvium, there is buried a great quantity of the bones of whales, sharks, porpoises, mammoths, Asiatic elephants and other large animals, along with numerous trees, sometimes with their fruit. Layers of marine mud, are also found, deep beneath the diluvium, below the present low water mark.

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* We are not unwilling to concede every fact, that can fairly be claimed, by the ingenious writer, who would have the inhumed remains of elephants and other large animals, referred to the celebration of Roman and Tartarian games, and to their warlike movements; but he must not demand too much. What Roman or Mongul Tartar emperor, ever marched armies or held his court in either of the Americas, on the Ohio, in New Jersey and New York, or at Cheshire, near New Haven, and in innumerable other places, where the bones of the mammoth and of other gigantic animals have been found?

There are also vast quantities of shells, and especially of a gigantic oyster, in many parts of the southern states. They are found, not only in digging for wells, but they form vast beds in various places.

One of the largest beds on the eastern continent, is near Tours, in France; it is twenty seven miles long and twenty feet thick.

But the beds of the southern states far exceed this. A stratum, on the whole continuous, although mixed, more or less, with the general diluvium, and other materials of the country, has been traced from the Eutaw springs, in South Carolina, to the Chickasaw country; six hundred miles in length, by ten, or from that to one hundred, in breadth.*

There can be little doubt that many of the beds of oyster shells which have been attributed to the aboriginal Indians of this country are diluvial deposits.

The bones and skeletons of large animals, especially of the mammoth, are found in wide dispersion, and in very remote countries; in both Americas, in Europe and in Asia. In northern Asia, the tusks of the extinct elephant, are discovered in the diluvial banks of almost every river, and the ivory is found in such abundance, as to be a regular article of commerce. An enormous carcase,† of the northern or Asiatic elephant, a few years since, by the gradual thawing of the frozen bank, in which it was imbedded, high above the water, fell down and exhibited the flesh in full preservation; the long bristly hair and vast massy hide, requiring a large number of men, to carry it, afforded proof irrefragable, of the existence of the animal in those rigorous climates, and of his sudden extinction, inhumation and congelation, with so little interval of time, that putrefaction had not commenced, and has not since taken place, during a long succession of ages.

Indeed, there is but one view which appears to carry with it the least probability, as to the cause of the wide dispersion and sepulture of the gigantic races; especially of extinct animals in the various quarters of the world. It seems evidently to have been the work of the deluge, which at once drowned, and in many instances, extinguished whole races of animals, and buried their bodies in the wreck of the planet with which those waters were evidently filled. Such a scene of awful devastation, was as well fitted to produce these effects, as it was ill adapted, to the comparatively tranquil life and death of the successive generations of marine and aqueous animals, that peopled the early ocean in its middle and later stages. Organized remains are found at very high levels, not only mineralized but loose or in diluvium, thus proving the prevalence of the ocean, at different periods.

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* Mr. Finch in American Journal of Science, Vol. VII. p. 40.

† Notes to Cuvier's Introductory Discourse.

It is said that the skeleton of a whale lies on the top of the mountain Sandhorn, on the coast of the northern sea. The mountain is three thousand feet high, and there is no cause that could have conveyed the whale to that elevation, except a deluge rising to that height.*

So late as June 1824, the remains of a whale were found on the westernmost Stappen, a mountain in Finmarck, at an elevation of eight hundred feet above the ocean. The specimens which were reported to be vertebræ, were lost by shipwreck on their passage to England. Similar remains are said to exist also in North Fugeloe, another mountain in those regions.†

It is common to find trees and their members in the diluvium, and also in the known alluvium of rivers, &c. In general, they are not much altered; sometimes they are partially bituminized or verge towards lignite, or perhaps are really lignite; at other times, they are penetrated by acids and saline substances, and metallic minerals, as pyrites, are occasionally formed upon them.

It has been already said that there is no difference in the nature of the operations by which diluvium and alluvium are produced, and that we must resort to an induction of particulars in order to enable us to distinguish between them, but in most situations, especially those that are remote from rivers and moving waters, there is very little occasion for hesitation, in forming an opinion.

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* Penn, Vol. II. pa. 308. † Ibid.

Extinction of Animal Races by the Deluge.

We cannot reasonably doubt, that many of the skeletons and bones of the animal races, which we find buried in ancient diluvium, in caverns, and in fissures in rocks, were covered by the wreck and sediment of the deluge; others have evidently been covered since, by ordinary or extraordinary events, and our decision, as to the era to which we are to assign them, respectively, must depend on the circumstances of each particular case.

But, is it necessary to suppose, that all the *extinct* races of large animals, found in diluvium, were destroyed at the deluge? If the account of the animals that were preserved in the ark, is to be understood so strictly, as to include *every genus* and *every species*, then we need make no other variation in our conclusions, than that, while all the animals, except a few individuals of each species, perished in the deluge; and therefore, their remains may be naturally found in ancient diluvium; *some* genera and species, of which the representatives were preserved in the ark, with the other animals, have perished since, by unknown causes, so that their races have disappeared entirely from the earth. There can be no objection to this admission—it does not weaken, at all, our view of the peculiar and destroying effects of the deluge.* While we make this remark, we must not however forget, that the fish are not mentioned in the history of the deluge. The obvious answer to this is, that being tenants of the waters, they might well be left to take care of themselves.

Whatever difficulties may arise, from the universal prevalence of a stormy, agitated ocean, (at least stormy and agitated during its rise, although comparatively pacific after it had attained its height, and during its decline,) an ocean filled with the wreck of the surface, turbid with mud, and unfriendly to the preservation even of fishes, especially, as they include the species, both of salt and fresh water, and therefore of widely different habits: we may suppose, that a few might still escape destruction, and thus preserve the races, although the greater number evidently perished, along with the land animals. As might be expected therefore, we find the skeletons of large fishes, (whales, sharks, &c.) buried in ancient diluvium, or grounded on high mountains, especially where cold and ice have aided in preserving the remains from decomposition.*

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* Although it appears to me nearly certain, that most of the mastodons perished at the deluge, I have no objection to admitting, that some of them, whose skeletons are found, may have perished before, or since that event. Those that are buried in ancient diluvium, as that whose remains were recently discovered near New Haven, in the gravel arising from the decomposition of the old red sandstone rock, were clearly antediluvian, and probably destroyed by the deluge; while some that have been discovered, foundered in salt licks and marshes, may have perished by miring, as cattle do at the present day.

Preservation of Vegetables.

Without supposing that the ark was a green house, or a repository of antediluvian seeds, it would perhaps not appear incredible, that Noah, so long warned of the approaching catastrophe, which was to tear away the soil, and root up the forests by the force of rushing waters, should have preserved some of the more important esculent plants and seeds; a degree of care not exceeding that which is exercised by every leader of a colony, when passing over seas to a new abode. But, however this may have been, there is no serious difficulty in believing, that in an ocean, which, from its magnitude and depth, was probably never warmed to that degree that favors germination, or vegetable decomposition: seeds of almost every kind, may have floated, uninjured, during the short period of a year, (for we know that seeds and seed vessels, are actually floated from continent to continent, without losing their germinating powers,) and when the waters subsided, they would of course, at least those that were in favorable circumstances, again shoot and grow.

We know also that seeds lie uninjured in the earth for many years, for every movement of the soil in cultivation is sure, after a little repose, to bring up a new crop of plants, and successive crops spring up spontaneously, on the same ground, even when left untilled from year to year.

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* We do not refer to remains of fishes in the solid rocks, which obviously belong to the first ocean.

It is obvious also, that the roots of plants and trees, would again strike into the ground and vegetate anew, as soon as the waters were sufficiently withdrawn, and the kindly influence of the sun was felt.

There seems therefore no serious difficulty in the restoration of vegetation to the earth, after the deluge.*

The loose materials by which the surface was covered, were a mixture of all preceding soils, and therefore fitted for the immediate renewal of vegetation. Horticulture and agriculture, especially the cultivation of the vine, (which needs little besides sand, and sun, and moisture, to make it grow,) might therefore have been resumed immediately. As vegetation increased, the soil would of course improve in fertility, by a natural process of manuring.

SUBSIDENCE OF THE DILUVIAL OCEAN.

The retiring waters of the Noachic deluge occupied half a year in their descent; and thus time was allowed, for that gradual and comparatively tranquil deposit and arrangement of the ruins of the surface, of which we every where find the most decisive evidence.†

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* Nor does the diluvial action, violent as we have supposed it to be, *necessarily imply* the extirpation of *every* plant; an olive may have been plucked from the tree *in place*, protected by some peculiar circumstances of situation.

† Taking the Himmaleh mountains as the measure of the height of the deluge, it fell at the rate of about one hundred and forty feet in twenty-four hours, or a little less than six feet in an hour—which, although a rapid descent for a common tide, was slow, compared with the ascent of the diluvial waters; a *partial* deluge, pervading the earth for a year, could not have happened; it must have flowed all round the globe. Statical principles forbid us to suppose that it was accumulated over a part of the world, and not over the whole. I know not on what authority, physical or historical, any person is permitted to say, that its elevation was less, than to cover "all the high hills and mountains under the whole heaven."

Nothing in geology has struck me with more interest, than the beautiful arrangement, in strata, of the beds of sand, gravel, clay, loam and pebbles, which may be observed in every country. A section of a bank of any of these deposits—or better still, an avulsion or fall, which leaves the stratification exposed, without being obscured, by the rubbish, produced by digging, or by the sliding of loose sand—never fails to exhibit the effects of sedimentary deposit; sometimes horizontal—sometimes inclined at various angles, great or small—sometimes undulatory, and recording, in a language that cannot be misunderstood, the effects of subsiding water. The beds are not always in the order of the magnitude of the parts. Sometimes coarser gravel, or even pebbles, will form a layer, above fine sand, and then perhaps the order will be reversed, indicating that there were currents, and these, relenting and increasing, alternately, as they were impelled, probably by tides or storms, so that coarser or finer materials were transported and deposited, as the waters were more or less agitated; for currents must have existed to the last. Could these sedimentary deposits be now all removed, we should see the naked, scarred, and devastated skeleton of the planet, exhibiting the most decisive proof that it had been swept by violence, of which we find evident marks in the scratches and furrows, found in the fixed rocks, that are covered by diluvium.

If a section of the deepest diluvium could be made quite down to the solid rock, there can be little doubt, that, on the whole, the magnitude of the parts would correspond with the depth, and the larger fragments of these loose materials would often be found at the bottom. This does not render it improbable, that bowlder stones should be occasionally deposited on the surface, especially when they are found on the firmer materials, or on rocky ledges.

SUBSIDENCE OF THE PRIMITIVE OCEAN.

If it was necessary that the diluvial ocean should retire with moderation, it was indispensable that the primitive ocean should decline with extreme slowness, in order to give time for the various arrangements of firm materials, which were going on, and for the consolidation of the fragmentary and petrifaction rocks, with their extraneous contents of organized bodies, both vegetable and animal. We have no reason to suppose, that there was any miraculous interference to get rid of the water, and indeed the innumerable marine races, found in the rocks, prove its presence, during the gradual progress of their lives, death, and sepulture. A rapid retreat of the waters would have been entirely inconsistent with this state of things; it could have produced no other than the most destructive effects, and, instead of fitting the earth to become the abode of living beings, and of man, their lord, would have exhibited only a scene of the most frightful devastation, and a long time must have passed after the event, before it could have become habitable.

As the waters of the primeval ocean, after the mountains and hills began to be uncovered, would be pent up and forced into sluices and narrow passes, the rapidity and devastating effects of the currents would have been greatly augmented, and for a time progressively so, as the waters descended.*

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* It is obvious, that the retreat of the waters could not, upon physical laws, have been so rapid, as to have been compassed, with safety, to the surface, within three natural days, the period that must be allotted to it by those who understand the account of the time in the common sense; for two days had passed, before the tops of the mountains appeared, and every thing was finished on the evening of the fifth day, at least, to such an extent, that the ground was dry enough, to be fitted for the reception of man, and of the terrestrial animals, which were created the next day.

Now the Himmaleh mountains are nearly twenty-six thousand feet high; probably, they were then considerably higher, perhaps twenty-seven thousand; as every thing on the surface, indicates that the mountains have been much degraded by the wear of time. The drainage of the earth, to have been accomplished in three days, upon the supposition of twenty-seven thousand feet elevation, would have required a descent of three hundred and seventy-five feet in an hour, or nine thousand in twenty-four hours; or, if these mountains were only twenty-six thousand feet high, the drainage must have been at the rate of more than three hundred and sixty feet in an hour, or over eight thousand six hundred and sixty-six in twenty-four hours, or two thousand one hundred and sixty-six feet in the time of the descent of a common tide.

The difficulty would not be diminished by the supposition that the mountains were elevated from the bottom of the ancient ocean, for, if they rose within the time of a few days, the effects on the waters would have been still more violent; if they were rising gradually during an indefinitely long period, this supposition concedes the very point in discussion. Every geological theory supposes the mountains to have been in existence, before the earth was habitable, and the Mosaic history necessarily implies the same fact.

XXX.—VOLCANOS.*

Among the physical phenomena of our planet, none arrest the attention of its inhabitants more forcibly, than those connected with earthquakes and volcanos. These tremendous displays of power cannot fail to interest even barbarous nations, who consider volcanic craters as the residence of demons, and their eruptions as the demonstrations of their anger, and as the means employed by them to spread destruction. The missionaries in Owyhee, (Hawaii,)† have given us a very interesting account of the goddess Pele, and of the highly poetical mythology, which the natives have built upon her supposed dominion.

It is not surprising, that such terrific appearances should be imputed by barbarians, to the agency of a local deity, and that the visitations of earthquakes and volcanos, should be regarded as malignant and vindictive inflictions.

Much of the poetical machinery of the Greeks and Romans, was fabricated out of physical phenomena. The struggles of the Titans, buried beneath the mountains, by the anger of the gods, were assigned by poetry, as the causes of the earthquakes of Italy, and Vulcan and the Cyclops, according to the annals of fable, forged their thunder bolts in the bowels of Etna and of the neighboring Lipari islands.

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* This introductory notice of volcanos, is taken, principally, from the Am. Journal of Science, Vols. XIII. and XIV. having been prepared by the editor of that, and the author of the present work.

† See Ellis' Tour, and the analysis of it, Vol. XI. p. 1. of the American Journal.

But in modern times, since the exact sciences have received so much attention, volcanos have been studied with a philosophical spirit. Sir William Hamilton, Spallanzani, Ordinaire, Brieslak, Brocchi, Humboldt, Von Buch, Beudant, Mackenzie, Monticelli, De la Torre, Bory St. Vincent, Webster, Scrope, Daubeny, and others, have given us accurate statements of facts, and have reasoned upon them, with direct reference to the present state of physical science.

To Mr. Scrope, and Professor Daubeny, we are particularly indebted, for recent and very valuable observations and discussions. Mr. Scrope published, in 1825, his "Considerations on Volcanos," and, more recently, his "Memoir on the Geology of Central France." Professor Daubeny has also very recently published his "Description of active and extinct Volcanos."

All these works are of great value, and as they have not been republished in this country, it may not be improper to refer the reader, who may not possess the original works, to very full analyses of them, in the thirteenth and fourteenth volumes of the American Journal of Science.

While we entertain and express the highest respect for the authors of the works alluded to above, we wish to be understood, to attach the principal value to their precise, methodized, and copious statements of facts; with most of their conclusions we do, indeed, fully agree, but there are theoretical points in these discussions, which will probably never be settled, and about which there will continue to be a diversity of opinion.

Definition of a Volcano.

Professor Daubeny states the following distinction between active and extinct volcanos—the former includes all those which have been eruptive at any time since the existence of authentic records—the latter, those that have. within the same limits of time, exhibited no signs of activity, although incontestably of the same origin.

Thus, although a mountain should not exhibit a crater, and the usual figure and stratification of a volcano,—if its materials have "a vitreous aspect and fracture, together with a cellular structure—cells generally empty, and elongated in the same direction, and, if they have a glazed, internal appearance," there need be no hesitation in pronouncing that the materials are of volcanic origin.

1. *Extinct Volcanos of France and Germany.*

Much philosophical scepticism formerly existed with respect to extinct volcanos. They were vaguely referred to, but without decisive proof of their real volcanic origin; and many persons, very imperfectly qualified to judge of such questions, were sufficiently inclined to infer the existence of volcanos of former ages, wherever they saw a conical hill, or almost any hill, with a hollow on its summit, and porous stones, of whatever kind, were referred to a similar origin. It was a very imposing and sublime idea, that volcanic fire, still active in our planet, and still bursting forth, in many places, with destructive energy, had, in ages long past, exerted agencies still more extensive—covering provinces with ruins, and operating, even in the bed of the primeval oceans. The speculation seemed, however, to claim quite as much affinity with poetical, as with philosophical conceptions, and, it was not till the middle of the last century, that the subject of extinct volcanos began to be investigated with accuracy and skill.

The much disputed country of Auvergne, Velay, and Viverais, in France, has been often visited, and examined by able geologists, and we believe, that within a few years past, no one of them has left that region, without being convinced that it is of volcanic origin. The celebrated geologist, D'Aubuisson, visited the country in question, with the strongest belief, that he should find this district of Neptunian origin, but he returned a convert to the opposite opinion; a change, the more creditable to his candor, and to the vigor of his mind, because he had before published an able and interesting treatise, to prove that basalt, and especially the basalt of Saxony, was of aqueous formation.

The volcanic district of France, lies upon the river Rhone, nearly in the angle formed by it with the Mediterranean, and covers an area nearly square, of from forty to fifty leagues in diameter.

We have never visited that country, but the evidence of its volcanic origin, exhibited by Mr. Scrope and Professor Daubeny, confirming, extending, and giving precision to the observations of many previous writers, leaves not the shadow of a doubt, that the tremendous subterraneous agency of fire has covered this fine country with floods of molten rock; no more doubt, indeed, than that similar events have happened at Vesuvius, Cotopaxi, and Ætna.

With the aid of a fine series of specimens, from this very region;* with the full descriptions of the authors whom we have just named, and with the noble atlas—geological—geographical, and picturesque, of Mr. Scrope, illustrating the striking features of this interesting region—we feel the fullest conviction, that their conclusions are substantially correct; and we can easily imagine, that we see the floods of lava, pouring from the now quiet and cold craters, and that the skies of that part of France were once dimmed by the clouds of volcanic ashes, as those of Italy are at the present day.

Craters, regularly formed, often entire, sometimes with the thin and scorified edge of the lip in fine preservation, and occasionally of vast dimensions; here, black, rugged and scathed with fire; there, overgrown with trees, and there, filled with water, forming lakes; currents of lava, lying where they flowed from the crater, or where they burst from the side or foot of the ruptured mountain, extending many miles, and many leagues, traceable directly to their parent mountain, winding along the gorges and the sinuosities of the vallies, now and then diverted from their course by rocks, hills, and other obstacles; sometimes damming up rivers, whose courses they have crossed or obstructed, and thus forming lakes of considerable dimensions; exhibiting all the varieties of lithoid lava, from that which is compact and rock-like, to that which is porous and vesicular in an incipient, or in a prevailing degree; crowned or mixed with slag, scoriæ, pumice, olivine and other exuviæ of known and active volcanos; displaying frequently a structure, now spherical, ovoidal and concentric; now prismatic and columnar, and fronting streams, and bounding valleys, with ranges of columns, equalling or rivalling the regularity of the famous colonnades of Fingal's cave, and the Giant's Causeway; these are a few of the most striking features of these countries, which are so affluent in proofs of their igneous origin, that there is nothing needed, but to select carefully and judiciously, those facts which will be the most decisive, especially with respect to minds not familiar with such contemplations.

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*Furnished to the cabinet of the American Geological Society, by our celebrated geologist, Mr. William Maclure.

The volcanos of the Auvergne, &c. are regarded as of different ages; some appear to have been active before the formation of the present valleys, and some since; where the currents of lava have been cut through, by those causes which formed the present valleys, they are obviously older than the valleys, and where these currents have flowed into valleys, beds of rivers, &c. they are as obviously of a more recent date.

Although the local geographical names may be supposed to allude to the former character of the country, as Auvergne, (Avernus,) Valleé d'Enfer, &c. still, it is thought that these names convey no allusion to historical events, but rather to the actual appearance of the surface.

Although the formation of these volcanic regions was anterior to the records of history, it was evidently in the most recent portions, posterior to the existence of organized beings, which are found imbedded in the volcanic tufa.

Principal Volcanic Phenomena.

"They are commonly preceded by earthquakes of different degrees of intensity and duration, and with loud sounds or detonations, resembling the noise of ordnance and musketry, apparently produced by the disengagement of aëriform fluids, and the increase of bulk in the fluid rocks; and their sounds are conveyed through the solid earth, not by means of the air. The atmosphere, at this time, is remarked to be in a peculiar state of stillness, attended by a sense of oppression.

"During this period, also, springs are apt to disappear, so that wells become dry; and it is known that the extent of this affection is sometimes very considerable.

"When the eruption first appears, it is generally with sudden and great violence. Explosions, apparently from confined air, take place with loud noises, and succeeding each other with rapidity, and often with increasing force; the vent being, commonly, the central point or crater of the mountain. And in its attempt to escape, this air throws up fragments of rock, which sometimes fall back into the crater, and are again repeatedly projected, together with clouds of aqueous vapor. And as the fragments also are often broken into small pieces, and even into dust, this, uniting to the vapor, or mixing with it, produces dense black clouds, or smoke, often assuming the form of a column of entangled or successively formed clouds.

"Having arrived at a certain height, this column generally spreads laterally or horizontally, forming, if the air is calm, a shape, resembling that of a pine-tree, or if there be wind, a horizontal stream. Out of this cloud proceed lightnings of great vividness, while the falling of the dust, added to the density of the cloud, produces darkness over the surrounding country. The melted rock or lava now boils up in the crater, and is often so thrown up into jets by the extricated air, as to resemble flames; and at length it either boils over the edge of the crater, so as to run down the mountain, or else finds an issue laterally, by some crevice, equally flowing down in a stream, which holds its course as circumstances permit, down to the lower grounds.

"In the night this current is luminous; but in the day, it is generally obscured by vapors, or loses its light by the cooling and blackening of the surface. There are cases, however, in which no torrent of lava occurs, and where no other rocks than scoriæ are erupted. The greatest period of violence is generally over when the lava has flowed for a little while, or this is the crisis of the volcano. But commonly, the explosions of fragments and dust continue for some time, gradually diminishing, till the whole falls into a state of quiescence, and is finally extinguished. Lastly, it must be noticed, that from the action of the volcano on the atmosphere, clouds are generally formed in it, which produce falls of rain, often causing torrents, or even inundations.

"The intervals of repose are various, reaching in some cases as far as to many centuries; so that cultivation and population are renewed, to be dispersed again at some future day. In these intervals of repose, however, it is common for vapors to continue to be produced, either from the craters, or in the course of the currents of lava; and when these are sulphureous, they deposit sulphur; and in other cases, from their acid nature, they corrode and decompose the rocks through which they find a vent. What are called solfataras and souffrières are the result."*

The display of electrical phenomena during volcanic eruptions is often very brilliant; Mr. Scrope remarks that this was the fact with the eruption of Vesuvius, in October, 1822. "From every part of the immense cloud of ashes which hung suspended over the mountain, flashes of forked lightning darted continually. They proceeded in greatest numbers from the edges of the cloud. They did not consist, as in the case of a thunderstorm, of a single zigzag streak of light; but a great many coruscations of this kind appeared suddenly to dart in many directions from a central point."

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* Jour. Roy. Inst. No. 40, p. 356.

Stromboli appears to have been in ceaseless activity for at least twenty centuries, throwing out, not flames nor lava, but scoriæ. It is most violent before and during stormy weather, especially in winter, when lava is said to burst occasionally from its side into the sea, heating it to such a degree as to destroy the fish, which are cast on shore ready boiled.

This volcano is viewed by the fishermen as a weather glass, by which they augur the approach of tempests.

The volcano in the island of Nicaragua, called, by the sailors, the Devil's Mouth, is said to be constantly active, and this appears to be nearly the case also, with that of Kirauea, in the island of Owyhee, (Hawaii,) but these instances are very rare.

Many volcanos are in a state of moderate activity, with occasional paroxysms. Vesuvius was in this condition from the beginning of the present century to October, 1822, when there was a violent eruption. A similar state of things existed from 1767 to 1779, when a violent eruption gave vent to the force.

Ætna was eruptive with intermediate agitations in 1805–9–11–12 and 19, but both these volcanos have had periods of long repose, even for centuries.

Popocatepetl, in Mexico, has been active ever since the conquest of Mexico, and that of Sangay in Quito, has been in incessant activity for about one hundred years.

Mr. Scrope mentions as instances of remarkable volcanic paroxysms, those of Vesuvius, A. D. 79, 203, 472, 512, 685, 993, 1036, 1139, 1306, 1631, 1760, 1794 and 1822.

Ætna, in 1169, 1329, 1535; this latter eruption lasted two years "with terrific violence," and occurred after a quiescence of nearly one hundred years.

Teneriffe, in 1704, 1797–8.

San Georgio, one of the Azores, in 1808.

Palma, one of the Canaries, in 1558, 1646 and 1777.

Lanzerote, one of the same group, in 1730.

Kattlagia Jokul, in Iceland, in 1755, which lasted a year.

Skaptar Jokuhl, in 1783.

Violent eruptions are generally succeeded by periods of long repose, sometimes extending even to centuries. Decomposed lava forms a soil even in the crater, and vegetation springs up.

"All appearances of igneous action are effaced; forests grow up and decay, and cultivation is carried on upon a surface, destined, perhaps, to be blown to atoms, and scattered to the winds, when the crisis arrives for the renewal of the volcanic phenomena. Thus during the quiescent interval, between the eruptions of 1139 and 1306, the whole surface of Vesuvius was in cultivation, and pools of water and chesnut groves occupied the sides and bottom of the crater; as is at present the case with so many of the craters of Ætna, Auvergne, the Viverais, &c.

"Terrific eruptions occasionally break out from mountains not previously suspected to be of a volcanic nature, or in which the accounts, of former catastrophes of this sort, existed but as vague traditionary fables."

One of the most remarkable examples of the explosion of an entire volcanic mountain, happened in 1688, in the island of Timor, one of the Moluccas.

The whole mountain which was before this continually active, and so high that its light was visible, it is said, three hundred miles off, was blown up and replaced by a concavity now containing a lake.

Theories, suggested anterior to the discovery of Galvanism and the Metals of the fixed Alkalies and Earths.

It is necessary, to occupy very little time, either in reciting or discussing these obsolete theories. We wish, however, not to treat them, or their authors, with contempt; for they were, perhaps, the best that the then existing state of science presented.

"According to the first and most ancient of these, volcanos were attributed to the combustion of certain inflammables; similar to those which exist near the surface of the earth, such, for instance, as sulphur, beds of coal, and the like; and, in order to account for the spontaneous inflammation of these substances, an appeal was often made to an experiment of Lemery, which went to prove, that mixtures of sulphur and iron, sunk in the ground, and exposed to the influence of humidity, would give out sufficient heat to pass gradually into a state of combustion, and to set fire to any bodies that were near."

Brieslak supposed, that volcanos are produced by petroleum, collected in subterranean caverns, and kindled in some unknown way. Brieslak has shewn, that petroleum is very abundant in the globe; a conclusion which has been still further extended by the researches of Hon. George Knox.* It appears, that petroleum is found, abundantly, in the vicinity of volcanos, and that it is exhaled during their eruptions. The uniform presence of sulphur also, in volcanos, and its copious exhalation, during their state of activity, seem to countenance the general idea, that they may arise from the burning of combustibles.

There are many reasons why this theory, however plausible, appears untenable.

1. The quantity of any of the ordinary combustibles, which could be supposed to be present in any one place, would be totally inadequate to the effect. Reasoning, analogically, from our knowledge of other parts of the world—what supply of coal, bitumen, or sulphur could be adequate to sustain the fires of Vesuvius, or of Etna, of Hecla, of Cotopaxi, of Teneriffe, of Sumbawa, or of Kirauea! The most powerful beds of coal, are but a few yards in thickness, and a few miles in extent. A few capital operations of any principal volcano, would soon destroy the greatest existing bed of combustibles, and instead of continuing from age to age, as many of them do, all would soon be exhausted by the intenseness of their own energy, and the consumption of their inadequate magazines of fuel.

2. There are many volcanic countries, (indeed most are of this description,) where the geological structure and associations are such, as to forbid the existence of coal, the only combustible, sufficiently abundant to countenance such a theory. We should

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* See Vol. XII. p. 147, of the American Journal.

look in vain for many active volcanos, in countries of the coal formation, or of the anthracite series. Although volcanic fires, occasionally force a passage through any and every species of formation, there is reason to believe that they are deep seated—probably even in the primitive rocks, and in granite itself, where, of course, there is no coal and little sulphur.

3. When also (in the language of our author,) "we examine more narrowly into the analogies between the *effects* of volcanic fires, and of those which we know to result from the combustion of either of these materials, we are soon brought to confess the inadequacy of such an hypothesis to account for the facts before us. What resemblance, for example, do the porcelain-jaspers and other pseudo-volcanic rocks, as they are improperly termed, which we observe in coal mines, that have been for centuries in a state of inflammation, bear to the lavas and the ejected masses of a genuine volcano; or where do we observe from them the same evolution of aeriform fluids, and of streams of melted materials which are so characteristic of the latter?"

4. The fermentation of pyrites and the combustion of sulphur and bitumen and coal, do, without doubt produce certain effects, and sometimes those that are considerable; still these causes are totally inadequate to account for the prodigious extent, inconceivable energy, indefinite continuance, and successive reproduction, of volcanic phenomena.

It is plainly impossible, that such results should take their origin from a few comparatively trifling beds of common combustibles, and we must obviously seek for other causes more extensive and more powerful; and which are not limited in their range, their energy, or their capability of reproduction.

5. Gay Lussac urged, with much force, against the theory of burning combustibles being the cause of volcanic action, that the atmosphere cannot possibly penetrate to those seats of volcanic power, when there is brought into action a pressure capable of raising a column of melted lava, three times as heavy as water, to the elevation of one mile or several miles. The objection seems unanswerable, as far as the atmosphere is concerned:

although we may suppose, that the combustion is sustained by water, provided there are combustibles capable of decomposing that fluid, which would not be the fact, with either of the combustibles named, except coal, and that only at the temperature of intense ignition, which must not only be produced, but must also be sustained in some other way, as the affusion of water upon ignited coal, unless there is also a copious supply of air, soon puts an end to the combustion.

Earthquakes, &c.

"Some are unwilling to admit earthquakes, as any probable indication of subterranean fire, whilst others not only include them, but go so far as to class hot springs, gaseous exhalations, and the eruptions of mud and petroleum amongst volcanic phenomena."

Do earthquakes and volcanos depend upon the same cause? On this point, we conceive, that there can scarcely be any ground for hesitation.

Volcanic eruptions are invariably preceded, and accompanied by earthquakes, and when the volcano discharges its contents, the earthquakes immediately relent, and ultimately cease. It is plain, therefore, that those causes which produce volcanos do also produce earthquakes. But, it will be asked may not earthquakes be produced by other causes? To this inquiry we must answer, that we know not of any other causes that are sufficient to produce earthquakes, except those which modern science has assigned as the causes of volcanos, and, as these are, agreeably to the Newtonian rule, "*both true and sufficient*," we are bound to admit them, at least till other and more probable causes can be suggested.

"When we observe two volcanic districts, both subject to earthquakes, which are ascertained to have a connexion with the volcanic action going on, and find that an intermediate country, in which there are no traces of the operation of fire, is agitated by subterraneous convulsions, similar in kind, but stronger in degree than those which occur in the more immediate vicinity of the volcanos; have we not reason to conclude, that the same action extends throughout the whole of the above space, and that it is *this* which produces in the intermediate country the effects alluded to, which are only the more alarming from the absence of any natural outlet, from which elastic vapours might escape?

"Now in proof of the former of these positions, it may be scarcely necessary to do more than appeal to the case of Etna or Vesuvius, which rarely return to a state of activity, after a long interval of comparative quiescence, without some antecedent earthquake, which ceases so soon as the mountain has established for itself a vent.* Such was the case before the celebrated eruption of 79 in Campania, and in that of Etna in 1537, where, says Fazzello, noises were heard, and shocks experienced, over the most distant parts of Sicily. In such cases no one would doubt the connexion between the volcano and the earthquake."

Teneriffe, furnished with the volcanic vent of Teyde, enjoys comparative immunity, while the neighboring islands are dreadfully agitated. If it be objected, that earthquakes are too extensive to have their effects attributed to the same cause with volcanos, we may reply, that volcanic movements generally accompany or succeed them, although it may be in remote countries, and the earthquakes of one country are often connected with those of another.

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* Humboldt gives us the following series of phenomena, which presented themselves on the American Hemisphere between the years 1796 and 97, as well as between 1811 and 1812.

1796.—September 27. Eruption in the West India Islands; volcano of Guadaloupe in activity.
———November——The volcano of Pasto begins to emit smoke.
———December 14. Destruction of Cumana by earthquake.
1797.—February 4. Destruction of Riobamba by earthquake.
1811.—January 30. Appearance of Sabrina Island in the Azores. It increases particularly on the 15th of June.
———May———Begining of the earthquakes in the Island of St. Vincent, which lasted till May, 1812.
———December 16. Beginning of the commotions in the valley of the Missisippi and Ohio, which lasted till 1818.
———December——Earthquake at Caraccas.
1812.—March 26. Destruction of Caraccas; earthquakes which continued till 1813.
———April 30. Eruption of the volcano in St. Vincent's; and the same day subterranean noises at Caraccas, and on the banks of the Apure.
Pers. Narr. Vol. IV.

See also Gemellaro on the Meteorological Phenomena of Mount Etna, extracted in the London Journal of Science, Vol. XIV, 1818.

To account for the extent to which the vibration of the solid substance of the earth will communicate both shocks and sounds, Mons. Gay Lussac (" Annales de Chimie," &c. Tome xxii, page 429,) remarks, that a vibration of the earth is similar to that of the air; that it is a powerful undulation, produced in the mass of the earth, by some commotion, and that it is propagated, with the same celerity as sound. If we are surprised at the immense extent, to which the shock, the sound, and the ravages of an earthquake are perceived, we may be instructed by considering, that the shock produced by the head of a pin, at one end of a long beam, is distinctly perceived at the other, in consequence of a vibration of all its parts. The movement of a carriage upon the pavements shakes vast buildings, and is communicated through great masses of matter, as in the deep quarries under Paris. M. Gay Lussac inquires, therefore, whether it is astonishing, that a violent commotion, in the bowels of the earth, should cause it to tremble through a radius of many hundred leagues. This philosopher concludes, that earthquakes are the result of the communication of a commotion through the mass of the earth, so independent of subterranean caverns, (which some have supposed favorable to the propagation of the sound and motion) that these effects will be propagated the more extensively, the more homogeneous the materials of the earth are.

Our knowledge of elastic agents justifies us in concluding, that steam and gases, in a word, aeriform agents, as the immediate moving power, are the causes of volcanic eruptions, and of earthquakes. When evolved rapidly and suddenly,—that is, in very great quantities, in a given short time, and endowed by heat with great elastic power, they have, without doubt, sufficient energy to rend mountains, to raise floods of fiery lava—to project stones to great heights in the atmosphere—to rock alpine ridges, on their foundations, to heave the ocean into unwonted undulations

—to shake continents, and the solid globe itself, to its very centre. The effects of gunpowder, of fulminating preparations, and of imprisoned steam, when suddenly liberated, (now so familiar to mankind,) fully justify us in attributing to elastic agents, all that we have done in this statement.

This subject has been fully illustrated by Mr. Scrope, in his Considerations on Volcanos.*

Most hot springs have their origin from volcanic action.—Many that are not connected with active volcanic regions arise from basaltic rocks, and their composition is observed to be similar to that of the waters of volcanic districts, especially in their containing soda or the mineral alkali. It is possible that some hot springs—as, for instance, those of Bath and Bristol, may be derived from the fermentation of pyrites, or from other chemical agencies, generating heat, and that the permanency of the temperature may arise from the great depth, at which the chemical action, giving origin to the heat is sustained.

There can be no doubt that Water is a great agent in producing Volcanos.

Mons. Arago enumerates one hundred and sixty-three active volcanos, nearly all of which are situated near to the sea, "in islands and maritime tracts."

The apparent exceptions are few, and generally when examined, they will not prove to be real.

If there are, as is stated, but not fully confirmed, one or two volcanos in the centre of Tartary, they may communicate with the lakes of that country, some of which are saline.

Jorullo, in Mexico, is one hundred and twenty miles from the ocean—but Colima, on the Pacific, and Tuxtla on the Atlantic, may be regarded as the wings of a vast subterranean gallery, by which the waters of either ocean, may, ultimately, communicate with Jorullo, and we may presume, that a similar state of things exists with respect to the various mountain groups of Guatimala, Colombia and Chili.

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* See Am. Jour. Vol. XIII, page 108.

It does not appear to us important to insist, that the communication supposed, should, in every case, be with salt water. It is true, that muriate of soda is frequently sublimed in volcanos, and we may generally attribute this to the proximity of, or at least to a communication with the sea. But those great effects, for which water is necessary in volcanos, depend, not upon the foreign ingredients it may chance to contain, but upon its action in its own proper character, either fluid or aeriform, and upon the agency of its elements. It would, therefore in our view, not operate, seriously, against the reasoning founded upon the supposed presence of water, if volcanos should break out, or be discovered in the midst of our greatest continents. We are always at liberty to suppose a communication with water, when we have so much evidence of its existence in the bowels of the earth, in caverns, and internal lakes and springs, and rivers, besides the vast stores which we see on the surface.

As to the extinct volcanos of France and other countries, as neither history nor tradition reaches to the period of their activity, although the evidence of their ancient existence is unquestionable, we may, with good reason, refer their origin, at least, to the period, when the countries in which they are situated, were *sub-marine*, or, when water existed abundantly, on the surface, in natural hollows, forming lakes and inland seas, more or less extensive.* But, it must be allowed, that water at the bottom of the ocean, existing under an enormous pressure of we know not how many miles of fluid, would be much more prone to reach the seat of igneous agency through the natural chinks and fissures, by which the earth is, more or less, intersected, and therefore, this is an additional reason to prove, that the oceanic waters are principally active in producing volcanos.

It does not however follow, that the volcano, which is fed by the waters of the ocean, must, of course, be submarine; it may break out either through the communication, by which the water was admitted, or elsewhere, under the sea or the land, according to circumstances, depending upon the strength, nature, and connexions of the superincumbent strata.

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* This does not exclude the supposition, that some of these volcanos may have continued to be active after the land was uncovered, and after they had thus ceased to be sub-marine.

Professor Daubeny founds his explanation of the causes of volcanos, upon the very interesting discovery of Sir Humphrey Davy, "that the solid constituents of our globe all contain some inflammable principle, and owe their present condition to the union of this principle with oxygen," and he thinks it by no means improbable, "that at a certain depth, beneath the surface, at which atmospheric air is either wholly or partially excluded, those substances may still exist in their pure unoxidized state."

As they do not and cannot exist, at the surface of the ground, no analogous phenomena can happen under our observation, and we are, therefore, at liberty to reason strictly with reference to the known action of the subtances in question.

Water having access to them, would be decomposed, great heat would be generated, sufficient to melt the rocks and the stony matter, formed by the oxidizement of the metalloids; immense quantities of gas and of steam would be thus evolved, and all the mechanical effects so familiar in volcanic eruptions and earthquakes, would occur.

	The composition of the lava of Catania, near Etna, as ascertained by Dr. Kennedy, is,	That of Santa Vennera, Piedmont, west of Etna, is,
Silex,	51.	50.75
Alumina,	19.	18.5
Lime,	9.5	10.
Ox. Iron,	14.5	14.25
Soda,	4.	4.
Muriatic Acid,	1.	1.

Prof. Daubeny has reviewed the structure and mineralogical and chemical composition of the volcanic masses, in order to shew the correspondence of facts, with the theoretical views which he has adopted, and it must be allowed, that he has so far made out his case, that there appears to be nothing connected with volcanos, which is materially at variance with the supposition of their origin from metalloids, acted on by water.

There is good evidence that "volcanos have universally broken out amongst the older formations, or those most near to the nucleus, whatever it may be, of the globe." The lavas themselves appear to be the materials of primitive rocks altered by fire, and the accidentally imbedded fragments are portions of primitive rocks. It seems to be irresistibly inferred, that the seat of volcanic action is deep, because the immense masses ejected from such mountains as Vesuvius and Etna do not exhaust them—because the materials are raised to a vast height, as at Teneriffe and Cotopaxi, and because the mountains are not often shattered by the tremendous explosions, which would blow up any superficial strata into the air.

Conclusion.—Theory of Volcanos.

In concluding this account of volcanic phenomena, and of their possible and probable causes, we may be permitted to observe—

That the act of creative energy, admitted alike by religion and philosophy, necessarily implies the production of all the elements of which our physical universe is composed. How far these elements were originally united in binary, ternary, or still more complex combinations, we cannot possibly know. The revelation of this fact, not being necessary to our moral direction, has been withheld by the Creator, and we know only—that "In the beginning God created the heavens and the earth." As to the actual condition of the elements, at that primeval period, science may fairly enquire, and is justified in reasoning within the limits prescribed by our moral condition and intellectual powers.

In the present state of chemical science, our elementary bodies are divided, very nearly, between the two classes, combustibles and metals, which really form but one class—and those agents, which from their acting with peculiar energy upon the combustibles and metals, and altering their properties, are called by some, supporters of combustion;—they are oxygen and chlorine, and some add iodine.*

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* There seems to be no reason for mentioning the imaginary body called fluorine.

If we extend the idea of combustion, as several authors are disposed to do, to other cases of intense chemical action, especially if attended with the extrication of light and heat, we shall include the agency of the combustibles and metals upon each other, as well as upon the proper supporters of combustion. For our present purpose, it is quite immaterial which view is embraced.

If we suppose that the first condition of the created elements of our planet, was in a state of freedom; the globe being a mass of uncombined combustibles and metals, and that the waters, the atmosphere and chlorine, and iodine and perhaps hydrogen were suddenly added; it will be obvious, from what we know of the properties of these elements, that the reaction, awakening energies before dormant, would produce a general and intense ignition, and a combustion of the whole surface of the planet. Potassium, sodium and phosphorous would first blaze, and would immediately communicate the heat necessary to bring on the action between the other metals and combustibles, in relation to the oxygen and chlorine, and in relation to each other. Thus a general conflagration would be the very first step in chemical action.

In this manner might be formed the fixed alkalies, the earths and stones and rocks,—the metallic oxides properly so called—the sulphurets and phosphurets of the metals—the carburet of iron—the acids, including the muriatic, and ultimately the salts, and chlorides, alkaline, earthy and metallic, and many other compounds resulting either from a primary or secondary action.

In such circumstances, there would also be great commotion —steam, vapors and gases would be suddenly evolved in vast quantities, and with explosive violence; the imponderable agents, heat, light, electricity, and magnetism, and attraction, in various forms, would be active in an inconceivable degree, and the recently oxidated crust of the earth would be torn with violence, producing fissures and caverns, dislocations and contortions, and obliquity of strata; and it would every where bear marks of an energy then general, but now only local, and occasional. It is however obvious, that this intense action would set bounds to itself; and that the chemical combinations would cease, when the crust of incombustible matter thus formed, had become sufficiently thick and firm, to protect the metals and combustibles, beneath, from the water and the air, and other active agents.

As we are not now giving a theory of the earth, but merely stating the conditions of a problem, we forbear to descant upon many obvious collateral topics, or to pursue the primitive rock formations, through the vicissitudes which might have attended them. We do not even say, that we believe that such events as we have endeavored to describe, did actually happen; we say only that their existence is consistent with the known properties of the chemical elements, and with the physical laws of our planet. Supposing that such was the actual progress of things, it is obvious that the oxidated crust of the globe, would still cover a nucleus consisting of metallic and inflammable matter. Of course, whenever air and water, or saline and acid fluids, might chance to penetrate to this internal magazine, the same violent action which we have already supposed to have happened upon the surface, would recur, and the confinement and pressure of the incumbent strata, increasing the effects a thousand fold, would necessarily produce the phenomena of earthquakes and volcanos.

Still, it is equally obvious, that every recurrence of such events, must oxidize the earth deeper and deeper, and if the point should ever be attained, when water or air ceased to reach the inflammable nucleus, or the nucleus were all oxidized, the phenomena must cease, and every approximation towards this point would render them less frequent.

Does this correspond with the actual history of these events? Are they now less frequent, than in the early ages of our planet? The extensive regions, occupied by rocks of acknowledged igneous origin, but where fire is not now active, would seem to favor this idea, but the answer to this question must depend so much upon the theoretical views entertained of the formation of granite, and of the other primitive rocks, that it may be impossible, at present, to bring it to a decision.

Whatever we may think of the hypothesis now detailed, may we not suppose, with sufficient probability, that those Voltaic powers which we *know* to exist—whose action we can command, and whose effects, having been first observed within the memory of the present generation, now fill us with astonishment, are constantly active in producing the phenomena of earthquakes and volcanos.

Arrangements of metals and fluids are the common means by which we evolve this wonderful power, in our laboratories; and it would seem that nothing more than juxta position, in a certain order, is necessary to the effect. Even substances apparently dry and inert, with respect to each other, will produce a permanent, and in proportion to the means employed, a powerful effect; as in the columns of De Luc and Zamboni. It would seem indeed, that metals and fluids are not *necessary* to the effect. Arrangements of almost any substances that are of different natures, will cause the evolution of this power. Whoever has witnessed the overwhelming brilliancy and intense energy of the great galvanic combinations, especially of the deflagrator of Dr. Hare, and considers how very trifling, in extent, are our largest combinations of apparatus, compared with those natural arrangements of earths, salts, metals and fluids, which we know to exist in the earth, in circumstances similar to those, which, in our laboratories, are effectual in causing this power to appear, will not be slow to believe, that it may be in the earth, perpetually evolved and perpetually renewed; and now mitigated, suppressed or revived, according to circumstances influencing the particular state of things at particular places.

In our laboratories, we see emanating from this source, intense light, irresistible heat, magnetism in great energy, and above all, a decomposing power, which commands equally all the elements and the proximate principles in all their combinations.

Sir Humphrey Davy, after discovering that the supporters of combustion and the acids, were all evolved at the positive pole, and the combustibles and metals, and their oxidated products, at the negative—proved, that even the firmest rocks and stones could not resist this power, their immediate principles and elements being separated by its energy. The decomposition of the alkalies, earths, and other metallic oxides being a direct and now familiar effect of Voltaic energy—their metals being set at liberty, and being combustible both in air and water—elastic agents produced by this power, and rarefied by heat, being also attendant on these decompositions, it would seem that the first principles are fully established by experiment, and that nothing is hypothetical, but the application to the phenomena of earthquakes and volcanos.

It appears an important recommendation of the present view, that causes are here provided which admit of indefinite continuance, and of unlimited renovation. There appears no reason why, on the whole, the phenomena should cease, as long as the earth exists. It has therefore the great Newtonian requisites of a good theory; *its principles are true*, and *it is sufficient.*

It has this additional advantage—it embraces all that is possible in former theories. Coal, lignite, sulphur and petroleum, and fermenting pyrites, will all conspire with the great operations, at which we have so briefly hinted. Burnt substances will return again to their combustible condition, and combustibles will burn anew, in unlimited succession. Heat, light, electricity, magnetism, decompositions and recompositions without limit and without number,—the evolution of elastic fluids in boundless quantities, and all the violent mechanical effects, which their action is known to produce; these are among the known and familiar effects of this power, and all the materials, necessary to render it active, are existing in the earth, on a scale of immense extent. These suggestions might be fortified by many particulars. At present they are thrown out, as leading, although not entirely original thoughts.*

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* The present hypothesis does not exclude the subsequent action of water, in dissolving chemically, or disintegrating mechanically, the crust of the globe. If that which is described in the text, were the first state of the planet as it came from the hand of the Creator, the next step, as we certainly know, was to surround it with water; and then, water, fire, and all the great chemical agents cooperating; all that has been detailed in the preceding sketch would seem to follow, as a natural consequence.

SUMMARY.

1. *In the beginning, God created the heavens and the earth*, and established the physical laws,* by which the material world was to be governed.

2. The earliest condition of the surface of our planet, of which we have any *certain knowledge*,† was that of a dark abyss of waters, of unknown depth and continuance.

3. The structure of the crust of the planet affords decisive evidence of a series of events, in relation both to the formation of rocks, and to the creation and succession of organized bodies of which many of them contain such astonishing quantities.

4. Time, and order of time; event; succession and revolution are plainly recorded in the earth; and no history or tradition contradicts the supposition, that the events involved both time and order of time.

5. Geology cannot decide on the amount of time, but concludes that there was enough to cover all the events connected with the formation of the mineral masses, and with a great many generations of living beings, whose remains are found preserved in the strata.

6. The deepest rocks—the foundations upon which the others repose—being mainly crystaline, bearing marks of a chemical origin, and being destitute of fragments, and of organized remains, are regarded as the oldest, and are called primitive.

7. The rocks, called transition, are partly chemical and crystaline, and partly mechanical, and include remains of plants‡ and

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* Beautifully styled in sacred writ, "the ordinances of heaven."

† We do not *exclude* the *hypothesis* of an original action of fire; it is not material to decide whether the *very* first agency, was igneous or aqueous; it seems certain, that they were, very early, coexistent.

‡ Wood and terrestrial plants are found in most rocks, from the old red sandstone upwards, and in fact, in the order of rocks immediately beneath, *i. e.* the transition; proving that dry land must have existed, more or less, previous to, or at the time of the formation of most of these rocks. We may suppose, therefore, that ponds, lakes and rivers, existed also.—*De La Beche's View.*

marine animals,* and fragments of the primitive rocks upon which they lie.

8. The rocks, called secondary, include also chemical deposits, but less numerous and distinct, and their character is progressively more and more mechanical.

9. They contain numerous remains of plants and animals, in an entombed, and generally in a mineralized condition.

10. The organized deposits of the transition and secondary formations, belong to the primitive ocean, and prove that rocks were forming, by mineral laws, at the same time, that plants and animals were called into being, lived and died, and many of them were enclosed in the concreting rocks.

11. The existence of a universal primitive ocean is certain, and it was without a shore, till its diminution uncovered the tops of the highest mountains, and successively the lower elevations, and finally, such of the plains and valleys as were then formed.

12. Its retreat was gradual, and proceeded in such a manner as to be consistent with the due arrangement of the earth's crust and surface, and with the progressive creation, life, death and sepulture, of animals and plants.

13. Near the period of the earliest transition rocks, we find the beginning of the anthracite coal—perhaps a mineral creation—but, being associated with distinct impressions and remains of vegetables, and containing even fibrous charcoal,† we cannot deny an intimate connexion between the anthracite and the commencement of vegetable life.

14. The earlier animals are referred to a period not remote from this, and the transition and earlier secondary rocks contain abundance of encrinites, madrepores, molluscous shell fish, trilobites, orthoceræ, and other races, chiefly (as far as we know) extinct.‡

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*The terebratulæ have continued nearly without interruption, from the transition limestone, to the present time.—*De La Beche.*

† Which abounds in the anthracite of Pennsylvania.

‡ It cannot be expected, that every minor division of a formation should contain its peculiar fossil, which shall, at the same time, be characteristic of it, at great distan-

15. The earlier fragmentary rocks, make their appearance soon after the primitive, indicating, that mechanical causes—sometimes violent—were producing their effects.

16. It would appear, from the relics of the periods immediately succeeding, that vegetation had increased prodigiously upon the earth, and that there were even trees and forests upon those parts of the surface, that had become sufficiently dry.

17. Bituminous coal, belonging to the era of the earlier secondary, seems now to have been formed, as there is great reason to believe, from submerged and inhumed wood, and other vegetables, whose vestiges are so numerous in the coal mines.

18. Coal, being peculiarly limited in its local relations, and often contained in basins, it seems probable, that it generally arose from local circumstances, with all its alternating and attendant strata of shales, sandstones, limestones, clays, iron ores, puddingstones, &c.; and, as these depositions are often repeated several times, in the same coal basin, and the mines are occasionally worked to a great depth, (even to twelve hundred feet, in some places in England) it is plain that no sudden and transient event, like the deluge, could have produced such deposits, although it might bury wood and trees, which, in the course of time, might approximate to the condition of lignite or bituminized, or partially mineralized wood, which is often found under circumstances, indicating a diluvial origin.

19. We find, in the strata of this period, not only great abundance of shells, (bivalves, univalves, &c.;) but in the later, and sometimes in the middle secondary strata, oviparous animals, including several gigantic species of crocodiles* and other saurian amphibia.

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ces;—the general resemblance of the organic remains, contained in the more recent rocks, is a better guide than any fossils, supposed to be characteristic; though the latter become more valuable, as we descend in the series; the older rocks being much more uniform in their fossil contents, in parts of the world, far distant from each other, than the more modern.—*De La Beche's View.*

* The crocodile has been continued, perhaps, from the new red sandstone—certainly from the lias to the present time—and, as its remains often occur in the interval, the crocodile appears to have been a tolerably constant inhabitant of our globe,

20. In the secondary strata, above the bituminous coal,* we find perfect fish. Nothing can be finer in this way, than the ichthyolites, found in the lias limestone of England, and in the calcareous marl of Mount Bolca, near Verona, in which place, there are stated to be one hundred and five species.† They are numerous, at Beyroot, in Palestine,‡ at Sunderland, (Mass.) on Connecticut river, and in many other places.

21. Birds are very rare in the fossil state. Their habits would expose them, very little, to those accidents, by which the other organized beings were so abundantly inhumed, for even aquatic birds, have their nests on shore.

It is, however, remarkable, that in the recent secondary, and the tertiary, we first find remains of birds; they come in, in the strata, at the time when, we may presume, that the state of the planet admitted of their existence.

22. The loose materials, that cover the rocks, more or less, in every country, are attributable chiefly to the wearing effects of agents, operating, *in all time*, to produce disintegration and decomposition.

23. The primitive ocean appears to have had a greater agency than any other cause, in producing and rounding the bowlder stones and pebbles, and fragmentary materials, whether consolidated or loose; but the diluvial ocean, and the present ocean

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since its first appearance on the surface. The fossil crocodile appears to have been an inhabitant of fresh water, and of rivers, as at present. In the West Indies, the crocodiles frequent muddy, and sometimes brackish ponds, and in shallow water, they often remain for hours, with the tips of their noses out of water. The organization and habits of crocodiles, do not enable them to contend with the agitations of the sea, which they shun. It would seem, however, that the organization of the ichthyosaurus would enable him to swim in the waves.—*De La Beche's View.*

[*] Fragments of fish are stated to be found even in earlier strata.—*De La Beche's View.*

[†] Thirty-nine species are said to come from the Asiatic seas, three from the African, eighteen from South America, and eleven from North America—but in this distribution, imagination may have had a share, the resemblance being, perhaps, generic, rather than specific.

[‡] Am. Jour. Vol. X. pa. 28.

and seas, and waters, of every kind, including lakes, rivers, and rain and snow floods, and currents, operate in the same manner, and in the direct and combined proportion of time and energy of movement.

24. The actual disposition and arrangement of the loose materials, as we now see them, is to be attributed, chiefly, to the diluvial ocean—no other cause being capable of reaching the regions remote from, and elevated above the present great waters of the globe.

25. The arrangement of the loose materials, on shores, and in outlets, and in regions occasionally flooded, is, at least to some depth, and to some extent, to be referred to agencies now in operation.

26. Some materials are undergoing consolidation, in the progress of the present times; but, the masses thus produced, are limited and accidental, and are easily known by their loose and porous character, and *generally* by their want of firmness. They belong, for the greater part, to the tufas—the fragments and accidentals aggregates, being often cemented by infiltration of carbonate of lime, oxide of iron, or other substances; there is no difficulty in distinguishing them from the early formations.

27. Volcanic deposits obey no law; they are found wherever subterranean fire has accumulated sufficient power, to force a passage through the incumbent masses, and the lava, in fusion and ignition, flows over every thing, and in every direction, *qua data porta.*

28. The trap rocks and many of the porphyries, and the extensive deposits of ancient trachytic rocks, have the same accidental position, and occasionally cover any thing, and every thing, from granite to coal, and clay, and gravel, but appear to have abounded most in the earlier periods.

29. The analogies which favor the opinion of their igneous, but principally sub-marine* and often subterraneous origin, are numerous and strong, and the admission of this fact, militates in no degree, against the prevalence and peculiar effects of the primitive ocean.

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* Chiefly under the ancient ocean.

30. In the like manner, any rock, for whose ignigenous origin, derived from an examination of its character, contents and position, there appears sufficient evidence, may be referred to that cause, in perfect consistency with the early and indispensable dominion of water.

31. Thus the two great theories, that have so long divided geologists, may be made to harmonize, and nothing more remains than the perhaps superfluous task of settling the balance of power between them, and their auxiliaries, namely, pressure and the other modes of mechanical action, and the agency of the imponderable elements, which are closely connected with heat.

32. It is not necessary even to exclude the supposition that ignition and fusion may have preceded the period when the primitive ocean brooded over the planet, and as there is incontrovertible evidence of the ancient, as well as continued and present prevalence of internal fire, it is clearly *possible*, that it might have been in operation, as early as there were any materials upon which it could act.* It seems therefore a matter of little importance, whether the fire was kindled before or after water was poured round the globe. It is certain that they have maintained their separate dominion ever since, although with occasional coalition, and with great vibrations in the balance of power.

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It would appear from a notice in the public journals, that Professor Leslie considers it as certain, that the density of bodies increases as we descend below the surface of the earth, that air at the depth of thirty-three miles and three fourths, would have the density of water, and the density of quicksilver at one hundred and ninety-seven miles, that marble would have its density doubled at two hundred and eigthy seven miles, &c.

It is inferred that if the globe were solid, that its density would far exceed that of 5. and therefore, it is supposed that the earth must be hollow or cavernous.

The application of these opinions to some of the views which have been presented in the preceding sketch is obvious; they provide for the high specific gravity of the earth, not only in consistency with the existence of caverns; but caverns (a vast cavern,) are necessary to the theory. The learned author, as is stated, imagines that these caverns are filled with "*concentrated light*, which when embodied, constitutes elemental heat or fire," and the elasticity of this light is supposed to prevent the collapse of the walls of the cavity. On the latter very extraordinary suggestion, not having seen the author's own statement, we offer no opinion.

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* See the theory of volcanos in this sketch, page 98.

Conclusion.

It will be seen, that the only point in which the view, presented in the preceding sketch, differs from the common understanding of the Mosaic account of the creation is, not in the order of the events, but in the amount of time, which they are supposed to have occupied before the creation of man; every thing since that event, being understood according to the received chronology. In the prefatory remarks I have expressed the opinion, that there is no real inconsistency between the Mosaic history, and the actual structure of the earth. As I understand the account there is not, but, on the present occasion, I shall not enter upon the discussion of that part of the subject; believing that the period is not distant, when Geology will be admitted into the train of her elder sister Astronomy, and that both, however regarded while they were imperfectly understood, will be eventually hailed, as friends and allies of revealed religion.

REMARK.

In giving the limits of the Tertiary, it should have been stated, that it is always newer than the chalk and in England and France, lies upon it.

NOTE.—CORRECTION, p. 56.

The Megalosaurus is found in limestones and sandstones lying higher than the lias, and the ichthyosaurus and plesiosaurus are found also in many of the strata above, and in some of those below the lias.—*Comparison with De La Beche's View.*

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